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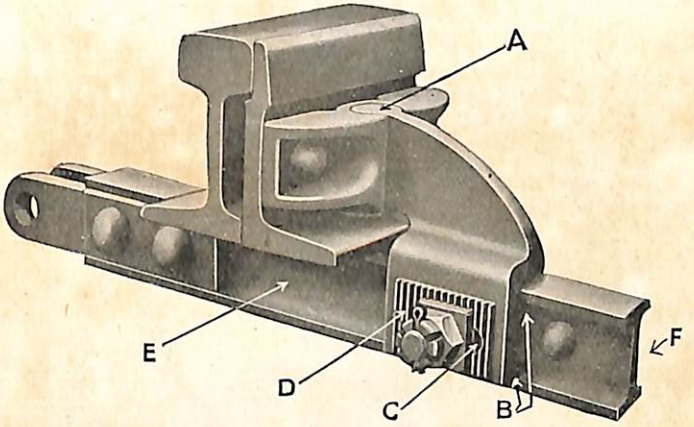

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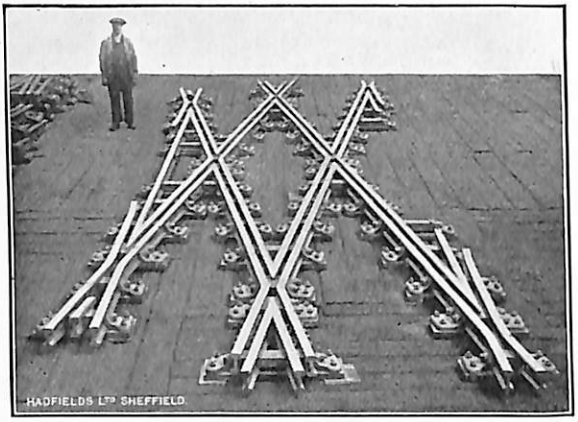

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RAILWAY POINTS AND CROSSINGS

A Survey of Problems Encountered in Actual Practice, and their Solution

BY

A. A. G. DOBSON

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SECOND EDITION

LONDON

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1928

PREFACE

THE diagrams in this book are more particularly intended for the Engineer or Draughtsman who finds himself called upon to prepare plans of turnouts, crossovers, or diamonds for places where the existing outlay does not admit the use of standard types.

All the cases dealt with have actually occurred during the course of the Author's routine work on railways.

A. A. G. D.

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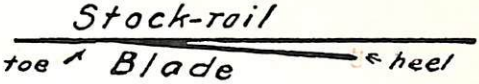
Railway Points and Crossings

SWITCHES OR POINTS

A SWITCH consists of a blade and a stock rail.



A set of switches consists of a right-hand switch and a left-hand switch.

Blades are generally straight, and are from 10 to 20 ft. long, according to the radius of the curve of the turnout. The method of arranging the blade with the curve of the turnout, *i.e.*, tangential or otherwise, admits of variation in its length, but whatever the accepted length of the blade may be it can always safely be modified a few inches in order that two or more blades may be cut from one rail without waste.

The "Toe" is the thin end of the blade, and the "Heel" is the thick end of the blade.

The distance the toe of the blade is moved from side to side by the points lever is called "Throw"—generally 3 or 4 in.

The distance at the heel of the blade to the stock rail is called "Clearance" (measured from running face of blade to running face of stock rail). It varies with the length of the blade and the width of the head of the rail, the minimum 'clearance' being that which allows the engine wheel to pass easily between the rail-heads.

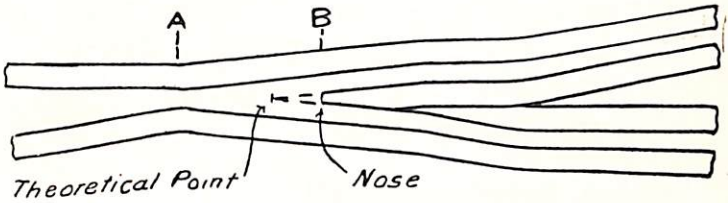
Points are called "Trailing" or "Facing," as they are "with" or "opposite to" the direction of the traffic.

CROSSINGS

A crossing occurs when one rail crosses another. There are two sorts of crossings—the "Ordinary," sometimes called "Acute," and the "Double," sometimes called "Obtuse." A crossing, whether ordinary or double, is usually described by its rate, not angle; rate is the cotangent of the angle, *i.e.*, 1 in 7, 1 in 8, etc.

Ordinary Crossing.—An ordinary crossing is from 10 to 13 ft. long, not too long for convenient

handling, or too short to rest upon at least five sleepers, one of which should be placed directly under the nose B and another directly under the elbow A.



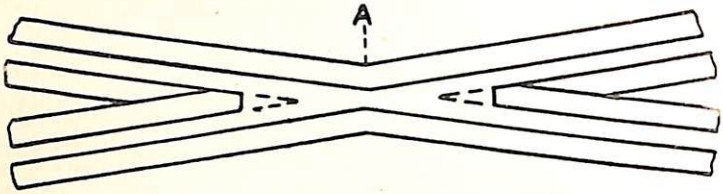
The 'legs' of the crossing may be made straight, as any deflection necessary for the curve in a railway turnout is seldom so great that the leg of the crossing cannot be adjusted to it, if necessary, on the site with a rail-bender. The advantage of the crossing being straight is, that it can be used for either right-hand or left-hand turnouts.

All measurements to an "ordinary crossing" are taken to the 'nose' of the crossing; not, however, to the actual 'blunt nose,' which varies in thickness, and so is indefinite as to position, but to a point called the "Theoretical Point," a few inches in front of the actual blunt nose—a point at which the running faces of the rails would intersect if continued on.

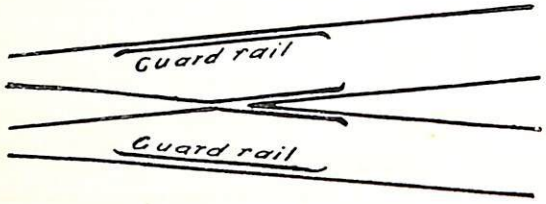
The space A to B is called the "Gap."

Double Crossing.—A "double crossing" has two noses, and is only used in diamonds; it is from 14 to 20 ft. long.

Measurements to a "double crossing" are taken to the centre A.



Guard Rails.—A guard rail (sometimes called check rail) is from, say, 10 to 20 ft. long, generally of such a length that two or more can be cut from one rail without waste. A guard rail must always face the gap in the crossing on both sides of it. The guard rails are attached to the running rails on either side of the crossing, as close to them as will just allow the flange of the engine wheel to pass. On no account must excess of clearance be given.



TURNOUTS

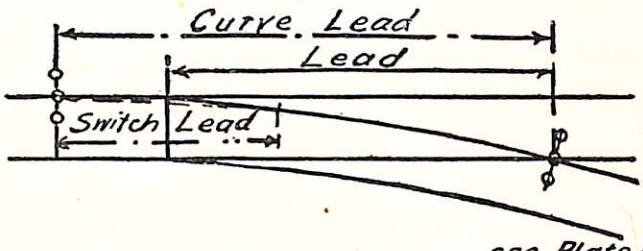
A turnout is made up of a set of switches and a crossing so arranged as to take a train out of one

track into another. Turnouts are described as "Left-Hand" and "Right-Hand."

Turnouts from Straight Tracks.—The "Lead" of a turnout is the distance from the 'toe' of the blade to the 'theoretical point' in the crossing.

There are at least four different methods of arranging the points and crossing with the curve of the turnout, each of which gives a different lead :—

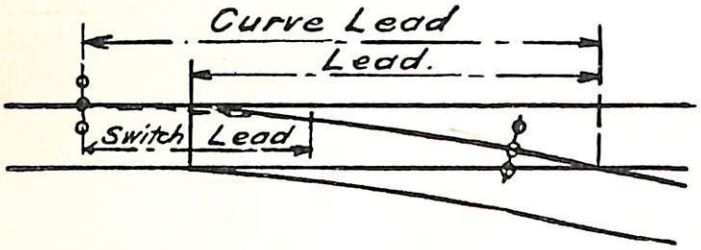
(1) The curved rail that 'makes' the crossing is tangential to one main line rail, and cuts the other main line rail at the angle of the crossing used. (The blade is fixed at that point on the curve at which the offset from the main line rail to the curve equals the 'clearance.') The distance from the tangent of the curve to the theoretical point in the crossing is



see Plate No 1 (page 53)

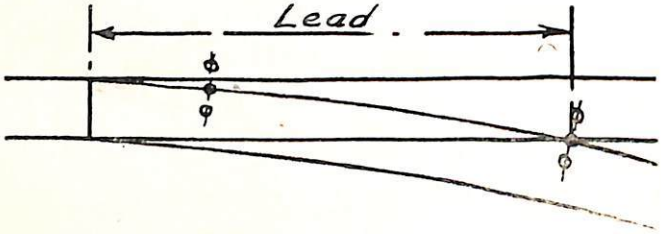
called "Curve Lead." The distance from the tangent of the curve to the heel of the blade is called "Switch Lead." The 'lead' is curve lead – switch lead + length of blade.

(2) The curved rail 'leading to' the crossing is tangential to the main line rail, and also to the straight leg of the crossing; (the blade is fixed at that point on the curve at which the offset from the main line rail to the curve equals the 'clearance.')



(2)

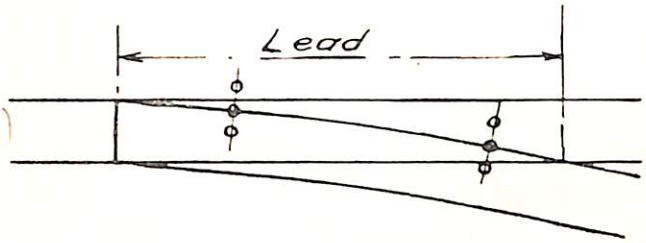
(3) The curved rail that 'makes' the crossing is tangential to the blade of the switch, and cuts the main line rail at the angle of the crossing used.



(3)

(4) The curved rail 'leading to' the crossing is

tangential to the blade of the switch and to the straight leg of the crossing.



see Plate N° 2 Page 55

Of these four methods of arranging the points and crossing with the curve of the turnout, No. 1 admits of the largest radius and is most often used; it certainly facilitates the calculation of leads for turnouts from curves of similar (or contrary) flexure. No. 4 is, however, theoretically the most correct.

A comparison of the leads and radii of the different methods is given below, where for each method the gauge is 4 ft. 8½ in., the crossing 1 in 8¼, the blade 16 ft. 6 in. long, the clearance 5 in., and in methods 2 and 4 the leg of the crossing is 3 ft. long.

Method No. 1	Lead = 71 ft. 3 in.	Radius = 647·95 ft.
,, ,, 2	,, = 69 ,, 2 ,,	,, = 598·26 ,,
,, ,, 3	,, = 75 ,, 3 ,,	,, = 617·70 ,,
,, ,, 4	,, = 73 ,, 3½ ,,	,, = 564·40 ,,

From the above it will be seen that there is a good

margin between the results of the different methods, so that a few inches more or less in the lead of a turnout is not a serious matter, and a slight modification of the accepted lead can safely be made to avoid cutting short pieces off closers.

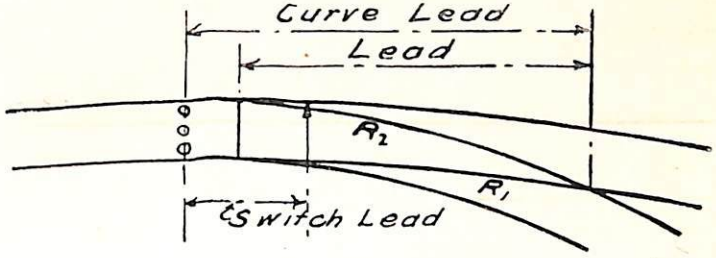
It is not recommended, however, that a lead be lengthened very much, as a long lead has the effect of making the radius of the turnout sharper near the crossing and flatter near the switch, whilst a short lead has the effect of making the radius sharper near the switch and flatter near the crossing, which is the better of the two, so that if a lead has to be modified on account of some local obstruction it is better to shorten it than to lengthen it.

Turnouts from Curved Tracks.—If the turnout is in the same direction as the curve of the main line it is described as a "turnout from a curve of similar flexure." If the turnout is in an opposite direction to the curve of the main line it is described as a "turnout from a curve of contrary flexure."

Turnouts from curves of similar flexure are more satisfactory than turnouts from curves of contrary flexure, as superelevation of the curved rails cannot very well be obtained on both tracks of the latter.

Turnouts from Curves of Similar Flexure.—In turnouts from curves of similar flexure flat crossings have to be used (say, 1 in $8\frac{1}{4}$ to 1 in 12), as the curve in the main line has the effect of making the radius of

the turnout smaller than would correspond to the same crossing used in a turnout from a straight main line. Thus on a 4 ft. $8\frac{1}{2}$ in. gauge on a main line curve of, say, 30 chains radius, a 1 in $10\frac{1}{2}$ crossing, in a turnout from a curve of similar flexure, is made by a radius of 10 chains approximately, whereas the same crossing in a turnout from the straight is made by a radius of 16 chains approximately.



The lead of a turnout from a curve of similar flexure has been found in practice to vary very little from the lead that corresponds to the same crossing used in a turnout from the straight; so that one standard lead can be used with every crossing of the same rate, whether the crossing is in a turnout from the straight, or in a turnout from a curve of similar flexure, or, as will be shown later, in a turnout from a curve of contrary flexure, no matter what the radius of the curve of the main line may be.

If it is necessary to calculate the lead, Coles' formula is recommended :—

g = Gauge in feet.

d = Clearance in feet.

R_1 = Radius of rail of main line that makes the crossing, in feet.

R_2 = Radius of rail of siding that makes the crossing, in feet.

a = Angle of crossing.

Required Lead—given R_1 . R_2, g . d.

$$\text{Curve lead} = \sqrt{\frac{2R_1R_2g}{R_1 - R_2}}.$$

$$\text{Switch lead} = \sqrt{\frac{2R_1R_2d}{R_1 - R_2}}.$$

Lead = Curve lead − switch lead + length of blade.

Other data may be calculated thus :—

Required R_2—given R_1, a, g.

$$R_2 = \frac{\left(R_1 + \frac{g}{2}\right)\frac{g}{2}}{R_1 \sin^2\left(\frac{a}{2}\right) + \frac{g}{2}}.$$

Required Angle of Crossing—given R_1, R_2, g.

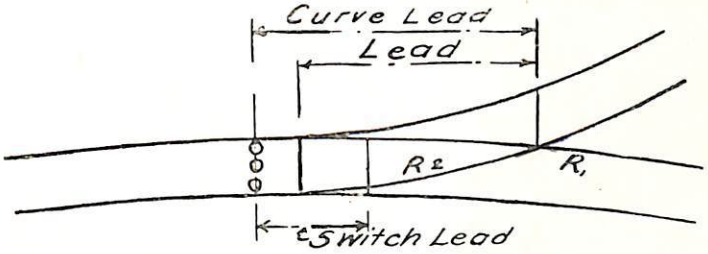
$$\sin\frac{a}{2} = \sqrt{\frac{\left(R_1 - R_2 + \frac{g}{2}\right)\frac{g}{2}}{R_1R_2}},$$

or, $$\text{Rate of cross } g = \sqrt{\frac{R_1R_2}{2(R_1 - R_2)g}} \text{ (approx.)}.$$

Turnouts from Curves of Contrary Flexure.—In turnouts from curves of contrary flexure wide crossings can be used, for the curve in the main line has the effect of making the radius of the turnout greater than would correspond to the

same crossing used in a turnout from a straight main line. Thus on a 4 ft. 8½ in. gauge, on a main line curve of, say, 30 chains radius, a 1 in 8¼ crossing in a turnout from a curve of contrary flexure is made by a radius of 14½ chains approximately, whereas the same crossing in a turnout from the straight is made by a radius of 10 chains approximately.

This is very fortunate, as 'flat' crossings are to be avoided on the 'outside' of curves on account of their long gaps, for the engine wheels cling to the outside rail of a curved track, and would derail in the gap of a crossing if the guard rail failed. A crossing on the 'outside' of a curved main line should not be 'flatter' than, say, 1 in 8½.



The lead of a turnout from a curve of contrary flexure, like the lead of a turnout from a curve of similar flexure, has been found in practice to vary very little from the lead that corresponds to the same crossing used in a turnout from the straight, so that one standard lead can be used with every crossing of the

same rate, whether the crossing is in a turnout from the straight, or in a turnout from a curve of similar flexure, or in a turnout from a curve of contrary flexure, no matter what the radius of the curve of the main line may be.

If it is desired, however, to calculate the lead, Coles' formula is recommended :—

Required Lead—given R_1, R_2, g. d.

$$\text{Curve lead} = \sqrt{\frac{2R_1R_2g}{R_1 + R_2}}.$$

$$\text{Switch lead} = \sqrt{\frac{2R_1R_2d}{R_1 + R_2}}.$$

Lead = Curve lead − switch length + length of blade.

Other data may be calculated thus :—

Required R_2*—given* R_1, a, g.

$$R_2 = \frac{\left(R_1 - \frac{g}{2}\right)\frac{g}{2}}{R_1 \sin^2\left(\frac{a}{2}\right) - \frac{g}{2}}.$$

Required Angle of Crossing—given R_1, R_2, g.

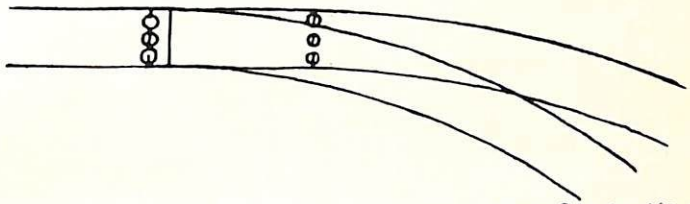
$$\sin\frac{a}{2} = \sqrt{\frac{\left(R_1 + R_2 - \frac{g}{2}\right)\frac{g}{2}}{R_1R_2}},$$

or, $$\text{Rate of cross } g = \sqrt{\frac{R_1R_2}{2(R_1 + R_2)g}} \text{ (approx.)}.$$

Turnouts on Track—Part Curved and Part Straight.—It occasionally happens that a turnout has to be put into the main line so close to the tangent of a curve that the crossing falls upon the curve and

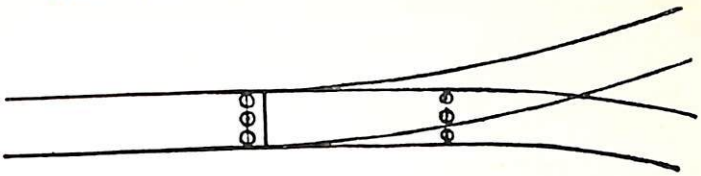
the points upon the straight. The turnout may be of similar or contrary flexure to the curve of the main line.

Similar flexure :—



see Plate No 3

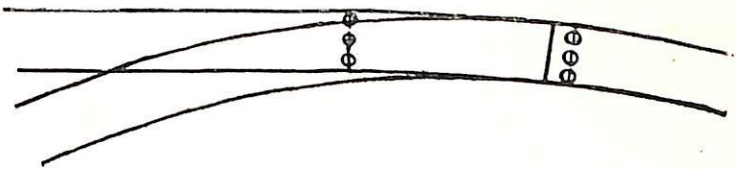
Contrary flexure :—



see Plate No 4

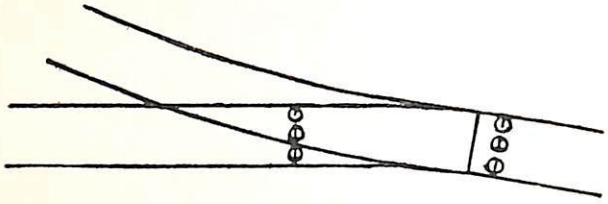
Or, the conditions may be reversed, the crossing falling upon the straight and the points upon the curve.

Similar flexure :—



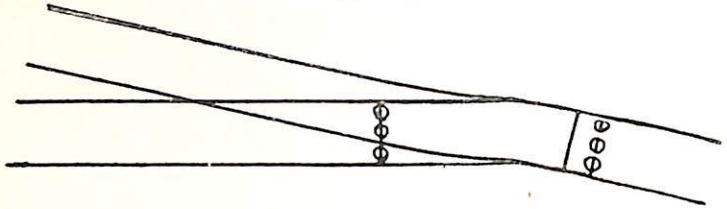
see Plate No 5

Contrary flexure :—

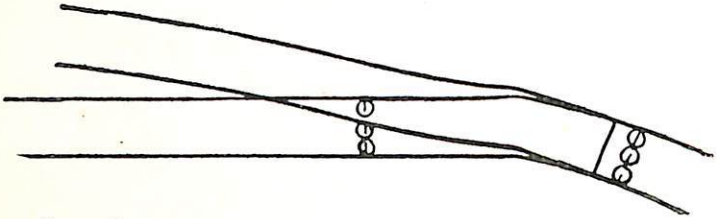


see Plate No 5

In this latter case, if the radius of the main line curve is smaller than the radius of the ordinary turnout from the straight corresponding to the crossing, the track leading to the siding may be quite straight, or



even curved in the same direction as the curve of the main line.



In all these cases radii and leads have to be specially calculated.

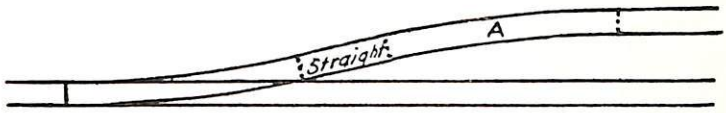
SIDINGS

A siding is connected with the main line, or another line, at one end or at both ends. If connected at one end only it is sometimes called a "Dead-End." If connected at both ends it is sometimes called a "Loop," especially if connected to a main line and used for allowing trains to pass one another.

Sidings and dead-ends are required to hold trucks and carriages which are not coupled to an engine, and for this reason must be level, or at least of a very flat grade. Loops are used to hold trucks and carriages which are coupled to an engine, and can therefore follow the grade of the main line.

The distance between sidings should be slightly more than the distance between double main lines, so as to allow space for shunters and porters to pass easily between the trains.

Straight Sidings Parallel to Main Line.—The

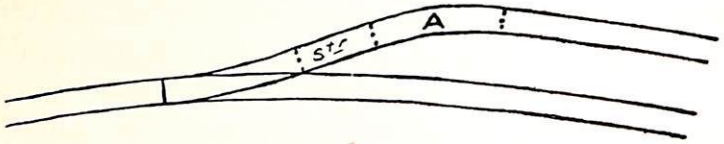


radius of the curve A is generally the same as that of the turnout. This admits of a piece of straight being introduced between the two curves which is desirable in a reverse. The straight should, if possible, be as long as the wheel-base of the engine.

On double main lines a siding is often connected with the track farthest from it, instead of to the track nearest to it, in order to avoid facing points. In this case a diamond must be used to cross the nearest track.

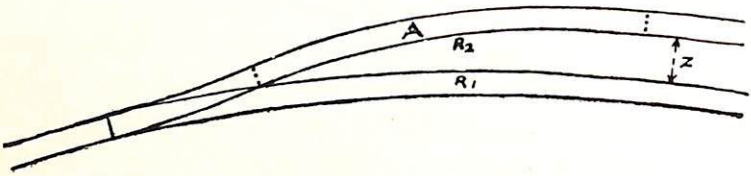
Curved Sidings.—Curved sidings usually follow the curve of the main line. They may be either on the inside or outside of the curve.

Concentric Siding on Outside of Curved Main Line.—If the siding is on the outside of a curved main line, a wide crossing should be used (see Turnouts from Curves of Contrary Flexure).



see Plate No 7

The wide crossing, unfortunately, sharpens the radius of the curve at A, and on account of this it will generally be necessary to start the curve A at the crossing itself without being able to allow the usual piece of straight in the reverse.

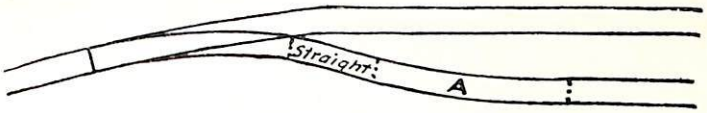


The maximum radius of the curve A can be found by substituting z for g in Coles' formula for "Turnouts from Curves of Similar Flexure."

$$R_2 = \frac{\left(R_1 + \frac{z}{2}\right)\frac{z}{2}}{R_1 \sin^2 \frac{a}{2} + \frac{z}{2}}.$$

If this radius so found is not large enough, the distance z between the tracks must be increased.

Concentric Siding on Inside of Curved Main Line.—If the siding is on the inside of a curved main line, a flat crossing will have to be used (see Turnouts from Curves of Similar Flexure).



see Plate Nº 8

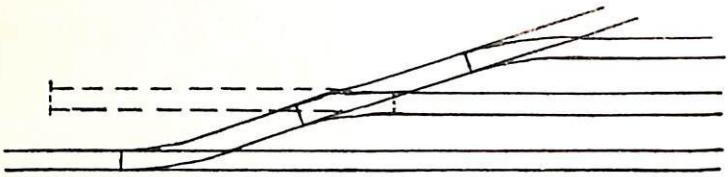
The difficulty, in this case, will not arise of too sharp a curve at A, and it will generally be found possible to have a suitable piece of straight between the reverse.

GATHERING LINES, OR LADDER TRACKS

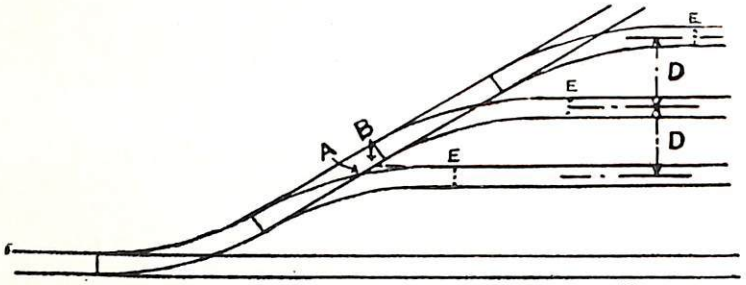
When there are several sidings there will be one line from which all the sidings branch off. This

line is called the "Gathering Line," or "Ladder Track."

Gathering Lines for Straight Sidings.—The angle of the gathering line to the sidings in a well-designed yard should be that of the crossings used. This will allow of any one of the sidings, if necessary, being carried through the gathering line to form a dead-end, or shunting neck (shown dotted), a diamond and slips taking the place of the turnout.



If the gathering line is already laid and is found not to be at an angle to the proposed sidings of any stock crossing, a crossing of a flatter angle than the angle of the gathering line to the proposed sidings must be used, for if a crossing of a wider angle were



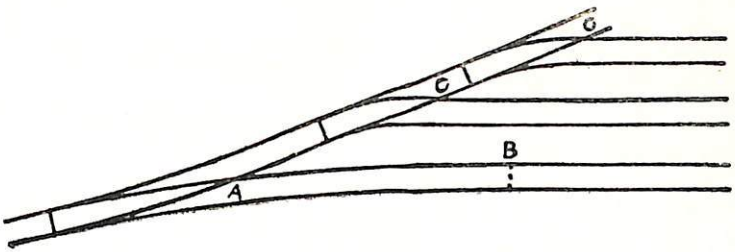
see Plate No 9

used, reverse curves into the sidings would occur. In cases where the flatter crossing is used, the curve of the turnout must be continued on through the crossing until it tanges with the siding at E.

The distance AB which is required by the platelayer to lay out the siding is called " Set Back."

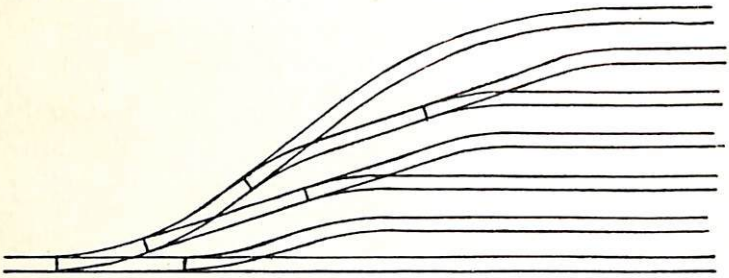
If the distance D between the sidings is fixed, the angle at which the gathering line can be set to the sidings is limited, for the greater the angle of the gathering line to the sidings, the shorter will be the distance between the crossings ; and in order to have sufficient room to give proper leads to the turnouts, the angle the gathering line makes with the siding must not be allowed to exceed $\sin b = \frac{D}{C}$, $\sin b$ being the angle of the gathering line to the sidings, D the distance between the centres of the sidings, and C the lead of the turnout + the length of the stock rail that overlaps the blade + the length of the leg of the crossing.

If the gathering line starts on a curve on the main

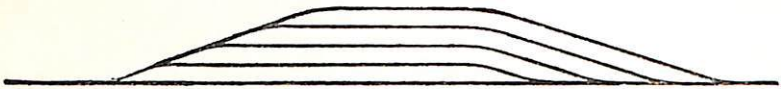


line, but so close to the tangent that the sidings can be laid straight, the angle of the crossing A will be less than the angle of the crossing C by the angle subtended by the arc AB.

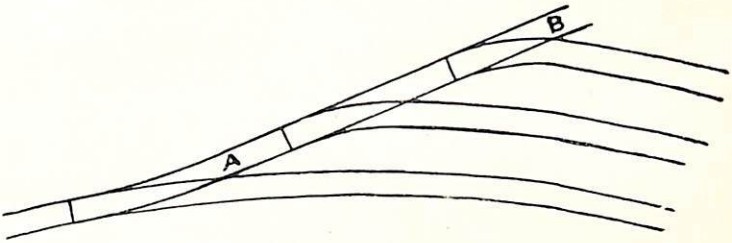
An arrangement in which the gathering line is put at twice the angle of the crossings, allows of a little more length in the outside sidings.



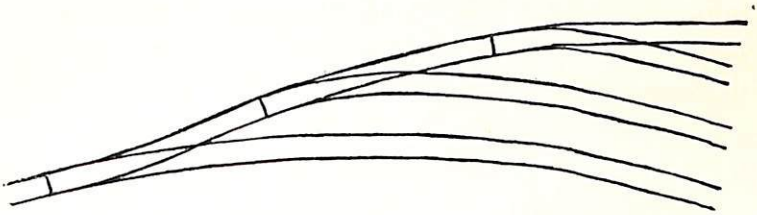
In marshalling yards and goods yards where it is convenient to have all the sidings of the same length, an arrangement may be adopted called the "Herring-Bone Grid."



Gathering Lines for Curved Concentric Sidings.—If the sidings are curved and the gathering line is straight, the angles of the crossings will increase in the direction of A to B.



If the gathering line is curved to the same radius as the main line, the angles of the crossings will all approximately be equal.

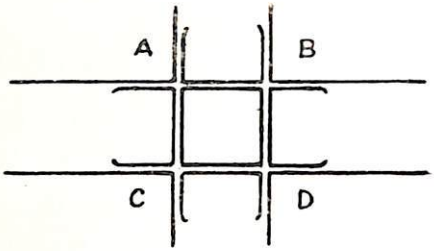


SQUARE CROSSINGS

When one track crosses another track at an angle of 90°, a "Square" or "Right Angled" crossing occurs.

A square crossing is either made up of four separate pieces, A, B, C, and D, or two separate pieces, AB and CD.

Square crossings are not very satisfactory in practice, as the wheel flange grooves in the rail-heads



on either side of the track face one another, and it is impossible for rolling-stock to pass over without jolting. A square crossing should not, of course, be used on a grade.

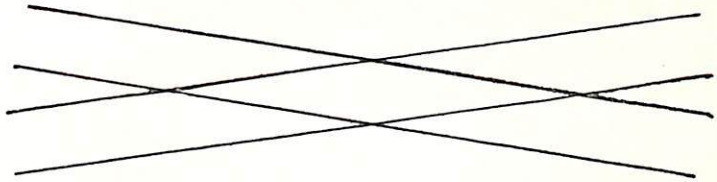
DIAMONDS

When a track crosses another track at an angle of less than 90°, a diamond occurs. A diamond is made up of two ordinary crossings and two double crossings.

Diamonds may either be straight or curved.

Straight Diamonds.—In a straight diamond all the crossings are equal.

A straight diamond should not be flatter than, say, 1 in 9, for the double crossings in a diamond almost face one another, and if the gaps in the crossings are very long, the engine wheels will dip into them when passing over.

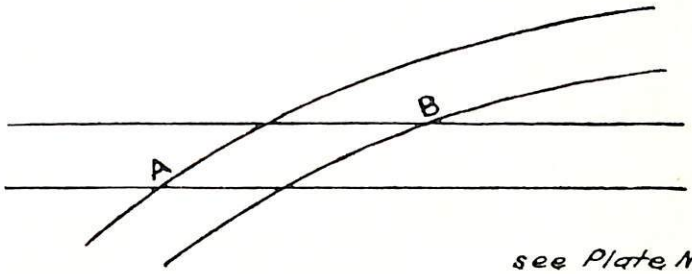


see Plate No 10

Curved Diamonds.—In curved diamonds one track only may be curved, or both tracks may be curved.

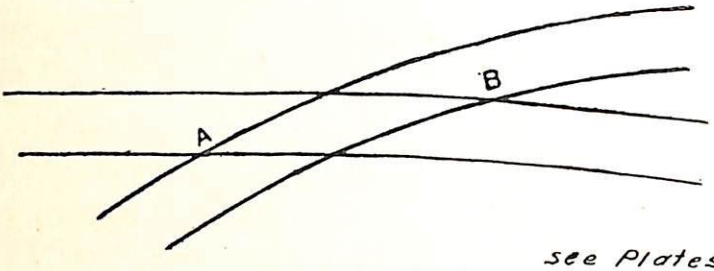
The double crossings in curved diamonds should not be flatter than, say, 1 in $7\frac{1}{2}$, for long gaps in the double crossings of curved diamonds are even less desirable than in straight diamonds, as, in addition to the possibility of the engine wheels dipping into them, there is the difficulty of guard railing them to contend with.

One Track Curved and One Track Straight.—When a curved track crosses a straight track, the angles of the crossings diminish in the direction of A to B.



see Plate No 11.

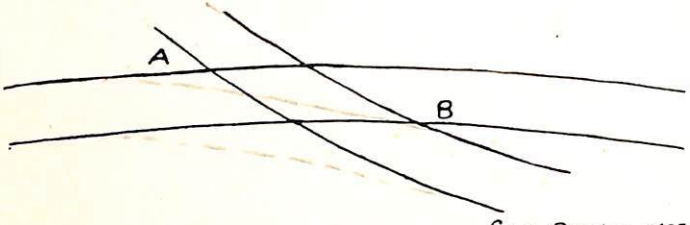
Both Tracks Curved—Similar Flexure.—When two curved tracks of different radii cross one another, the curves being of similar flexure, the angles of the crossings diminish in the direction of A to B.



See Plates Nº 12 & 13

When two curved tracks of the same radius cross one another, the curves being of similar flexure, all the crossings will be approximately equal, and the distance A to B approximately that of a straight diamond of the same angle.

Both Tracks Curved—Contrary Flexure.—If two curved tracks cross one another of either the same or different radii, the curves being of contrary flexure, the angles of the crossings will diminish in the direction of A to B.

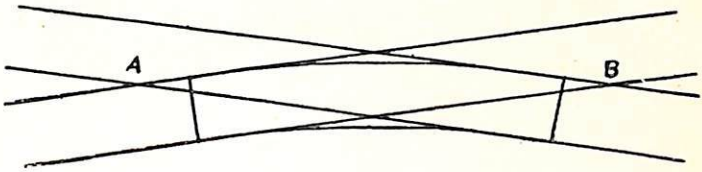


See Plates Nos 14 & 15

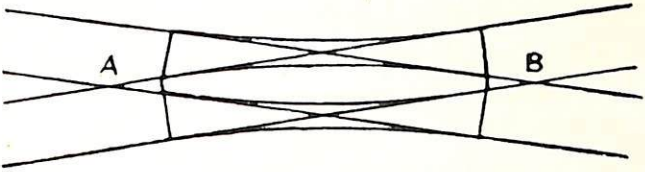
SLIPS

Slips may be either single or double. Single slips consist of two sets of points put into a diamond. Double slips consist of four sets of points put into a diamond.

Single slips :—



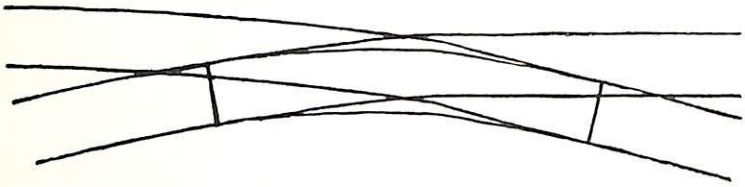
Double slips :—



The radius of the slips will practically be that of a turnout from the straight of the same crossing angle as the diamond, although actually it may be less, for the points have to be fixed at such a distance from the crossings A and B as will allow them to clear the fastenings of the crossings ; and if, for this reason, the lead has to be short, the radius of the curve will be correspondingly reduced.

Slips can be put into the inside of curved diamonds of large radii (say 30 chains minimum), the curves

being of similar flexure and equal radii. In this case the radius of the slips will be very much smaller than that which corresponds to a turnout from the straight of the same crossing angle as the diamond.



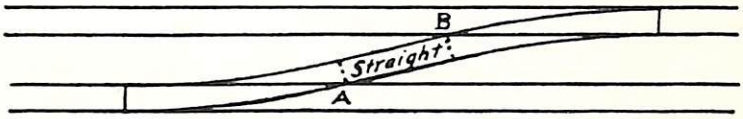
CROSSOVERS

A crossover is to take a train from one track into another. A crossover may cross other lines in doing so, in which case it is called a "crossover on three tracks" or "four tracks," etc., as the case may be. A crossover is made up of two turnouts and an intermediate portion. It may occur on straight tracks or curved tracks.

Crossovers on Two Tracks

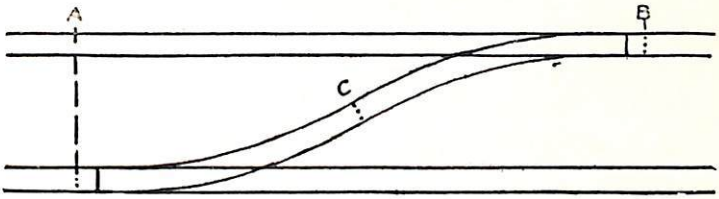
Crossover on Two Parallel Tracks.—In a crossover on two parallel tracks the intermediate portion A to B is generally straight, which is desirable in reverse curves; the closeness of the tracks, indeed, in practice, prevents it being otherwise if straight

crossings are used, as the legs of the two crossings almost overlap.



see Plate No 16

If, however, the tracks are wide apart and it is desired to minimise the total length of the crossover, curved crossings may be used, and the curves made to reverse in the centre at C without any straight intermediate portion.



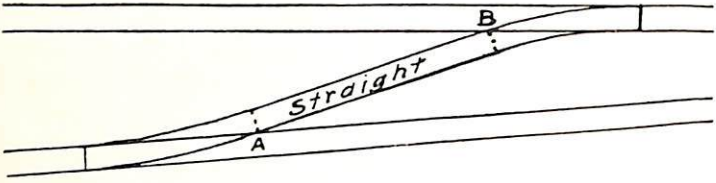
The distance AB may be calculated thus :—

R = Radius of centre line of curves.
D = Distance between centre lines of tracks.

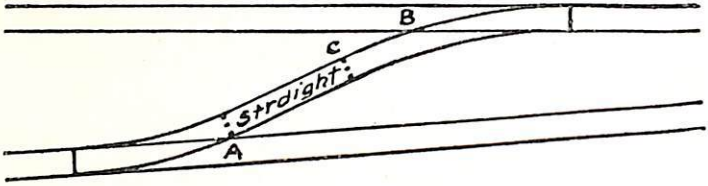
$$AB = 2\sqrt{R^2 - \left(R - \frac{D}{2}\right)^2}.$$

Crossover on Two Straight Tracks not Parallel.—If the tracks are not parallel and the intermediate portion of the crossover is straight, the

angle of the crossing at B will exceed the angle of the crossing at A by the angle the two tracks make with one another.

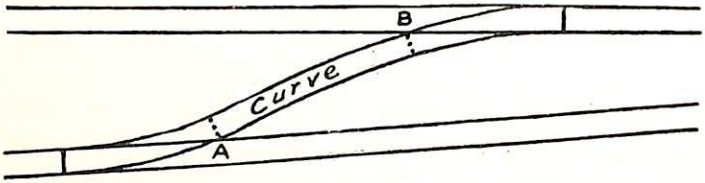


If it is desired to use crossings of the same angle, the curve at B must be continued on to tange with the straight at C, thereby making necessary the use of a curved crossing at B.



see Plate Nº 17

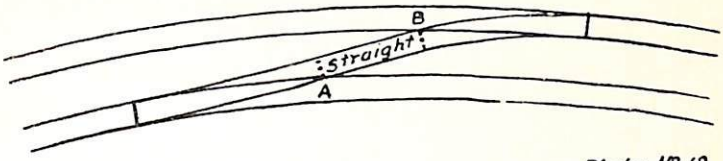
A way to avoid the curved crossing at B would be to curve the whole distance between A and B ; the curve



see Plate Nº 18

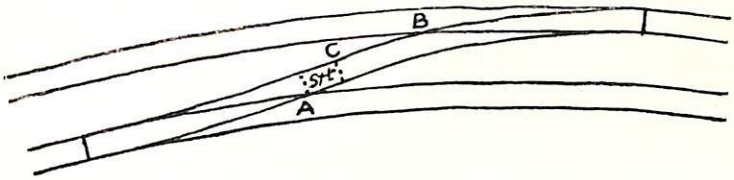
would then be flat enough for a straight crossing to be used at B, as the slight deflection necessary for the curve in the leg of the crossing could be put to it with a rail-bender on the site.

Crossover on Two Curved Concentric Tracks.—If the intermediate portion of the crossover is straight, the angle of the crossing at B will be greater than the angle of the crossing at A.

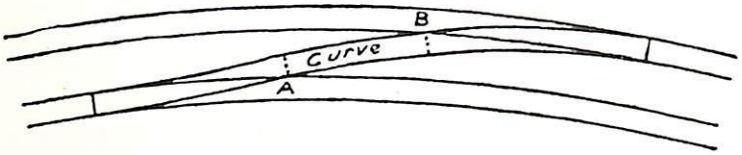


see Plate No 19

This is contrary to the principle defined in "turnouts from curves of similar and contrary flexure," which indicates the flatter crossing on the inside of the curve and the wider crossing on the outside of the curve, and in order to have that arrangement it would be necessary either to put a curved crossing at B and continue on the curve to tange with the straight at C (for method of calculating see Plate No. 7), or to curve the whole distance A to B,



whereby the curved crossing could be avoided, as the curve would be flat enough for a straight crossing



see Plate No 20

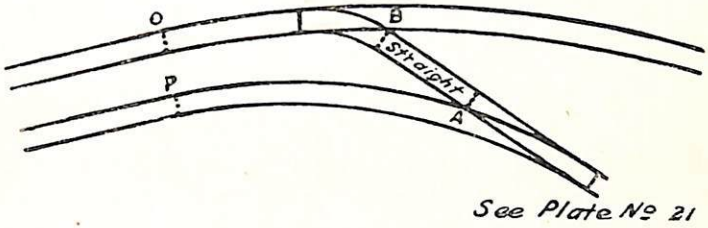
to be used, the slight deflection in the legs of the crossings, necessary for the curve, being put to them with a rail-bender on the site.

In this latter case, if crossings of the same angle are used, the radius of the curve to connect them will approximately be that of the curve of the main line, and the distance A to B approximately that of a cross-over of the same angle on a straight main line.

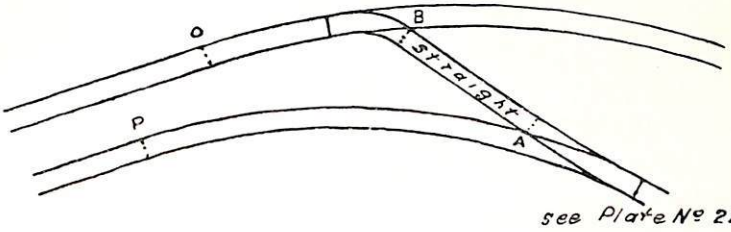
As mentioned previously, however, the closeness of the tracks in practice makes it impossible to put much curvature into the intermediate portion of any ordinary crossover, and if the main line curve is fairly flat the difference in the angles of the crossings will be very small, and it can generally be left to the platelayers to work in crossings of the same angle in the best way possible.

Crossover on Two Curved Eccentric Tracks.—There will be two cases of crossovers on two curved eccentric tracks.

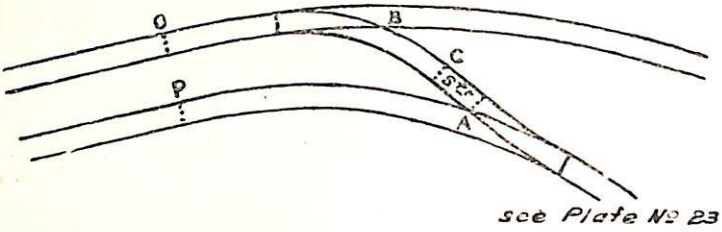
(1) The tangents O and P of the curves are opposite one another.



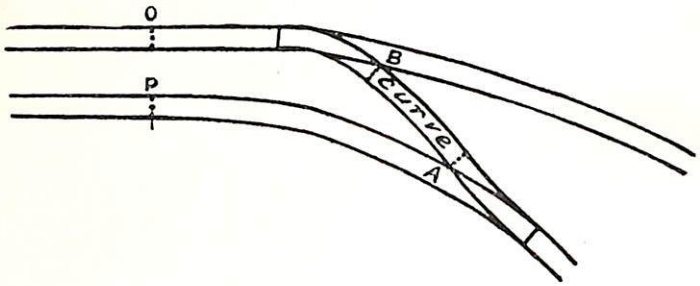
(2) The tangents O and P of the curves are not opposite to one another.



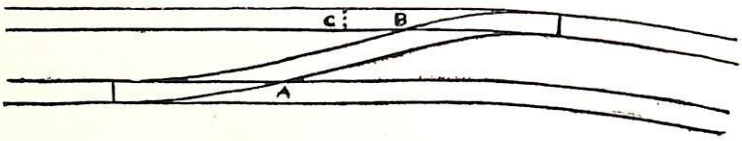
In both these cases if the intermediate portion B to A is straight, the crossing angle at B will be greater than the crossing angle at A. This is contrary to the principle defined in "turnouts from curves of similar or contrary flexure," which indicates the flatter crossing on the inside of the curve and the wider crossing on the outside of the curve, and in order to have that arrangement either a curved crossing would have to be put at B, and the curve carried on to tange with



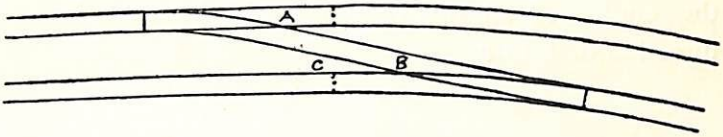
the straight at C, or a flat curve would have to be put into the whole distance B to A, the radius of which could be calculated by a process similar to that in Plate No. 20.



Crossovers on Two Tracks—Part Curved and Part Straight.—If the crossover is toward the outside track of the curved main line the angle of the crossing at B is greater than the angle of the crossing at A by the angle subtended by the arc CB.



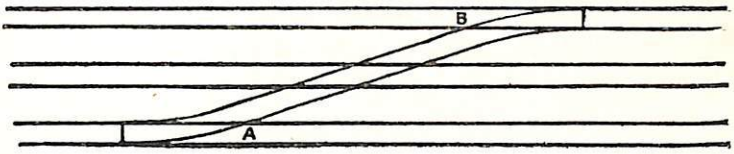
If the crossover is toward the inside track of the curved main line the angle of the crossing at B is less than the angle of the crossing at A by the angle subtended by the arc CB.



When, however, as is generally the case, the tracks are close together, the difference in the angles of the crossings will be so small that crossings of the same angle will be used, and the legs of the crossings adjusted on the site by the platelayer.

Crossovers on Three Tracks.—In a crossover on three tracks a diamond will be required on the intermediate track.

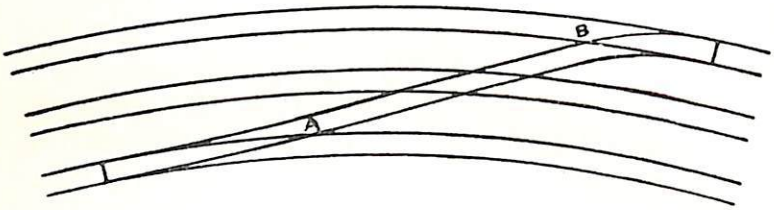
Crossover on Three Straight Tracks.—If the tracks are parallel and the intermediate portion A to B of the crossover is straight, all the crossings, both in the turnouts and the diamond, will be of the same angle.



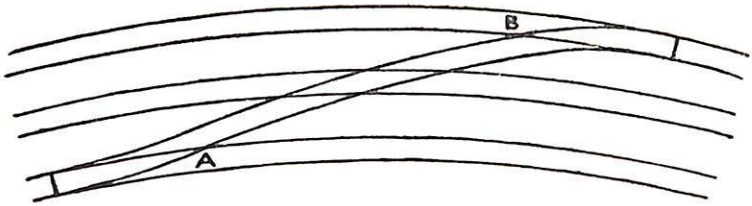
3

Single slips or double slips may be put into the diamond if required.

Crossover on Three Curved Concentric Tracks.—If the tracks are concentric tracks and the intermediate portion A to B of the crossover is straight, the angles of all the crossings will increase in the direction of A to B.

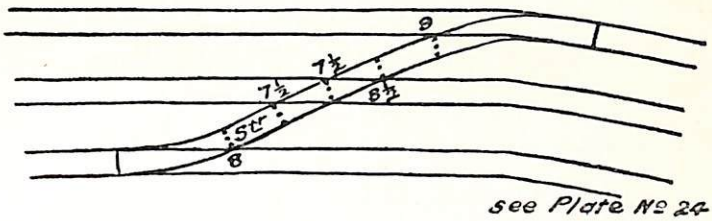


If the intermediate portion A to B of the crossover is curved to the same radius as the main line, all the crossing angles will be approximately equal.



This latter would appear to be the best arrangement, but unfortunately neither of the arrangements admits the use of wide double crossings which are recommended for curved diamonds, or for a flatter crossing at B than

at A, which is recommended in "turnouts from curves of similar and contrary flexure," and it is only by means of a compound curve that the proper conditions can be obtained.



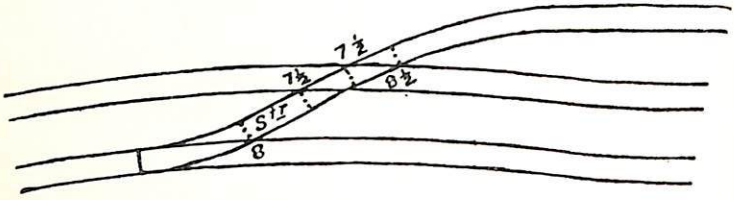
see Plate No 24

The closeness of the tracks in practice only admits of a gradual change in the angles of the crossings, and the rates shown will serve as a guide. The crossings should be selected first, and the radii of the curves to connect them calculated. There will be one radius between the crossings 1 in 9 and 1 in $8\frac{1}{2}$, another between the crossings 1 in $8\frac{1}{2}$ and 1 in $7\frac{1}{2}$, another between the crossings 1 in $7\frac{1}{2}$ and 1 in $7\frac{1}{2}$, and the track between the crossings 1 in $7\frac{1}{2}$ and 1 in 8 will be preferably straight. By this arrangement standard straight crossings can be used, as the slight deflection necessary for the curve in the legs of the crossings can be put to them with a rail-bender on the site.

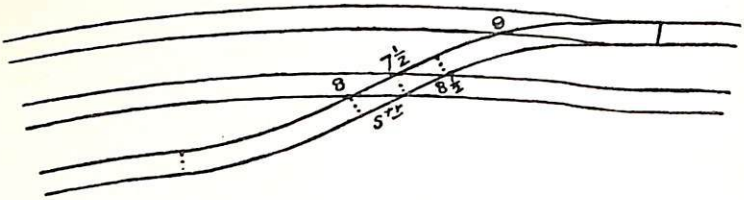
A modified form of this crossover occurs very often in the case of a connection to a siding from a curved double track, when, in order to avoid facing

points, the connection is made to the track farthest from the siding.

Siding on the outside of a curved main line :—



Siding on the inside of a curved main line :—



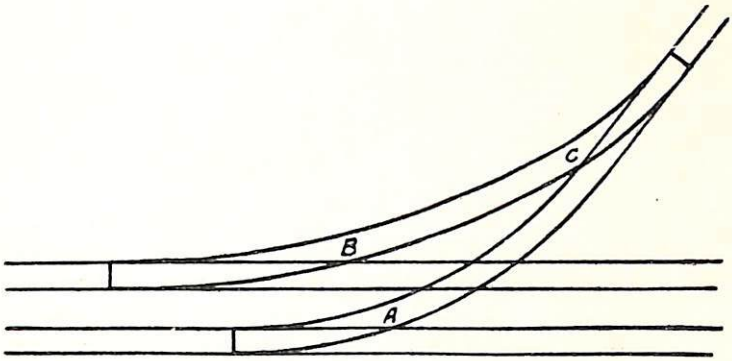
JUNCTIONS ON DOUBLE MAIN LINES

All junctions on double main lines should be level. A flat grade could only be allowed if rising in the direction of the branch line, for it is quite impossible to superelevate the rail of a curved diamond ; and if the grade of the main line were falling in the direction of the branch line, the rails in the diamond would be inclined in the wrong direction.

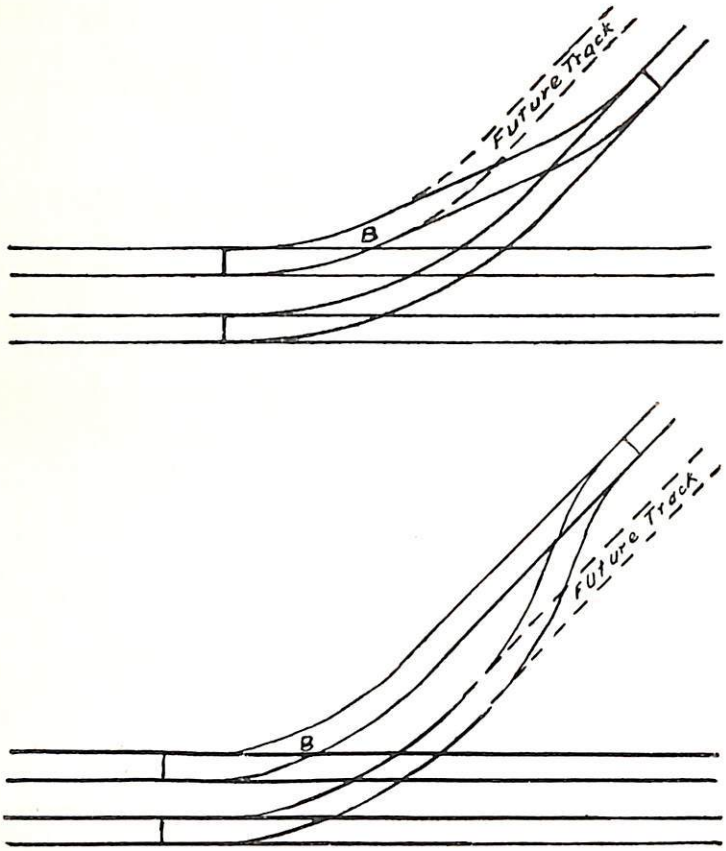
Junctions may occur on straight or curved main lines, and the branch line may be either single or double.

Junctions on Straight Double Main Lines

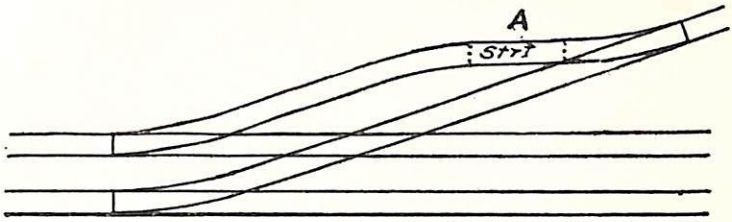
Junction of Single Branch Line.—If the angle the branch line makes with the main line is a wide one, greater than, say, 1 in $7\frac{1}{2}$, a curved diamond will have to be used, in which case the use of a flatter crossing at B than at A will allow of a continuous curve through B to C.



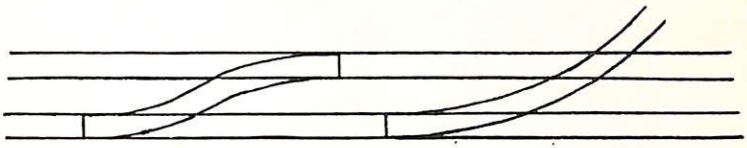
The possibility of future duplication would make one of the two arrangements below more economical, as the crossing at B could then remain. For method of working out the angles of the crossings in the diamond, see Plate No. 11.



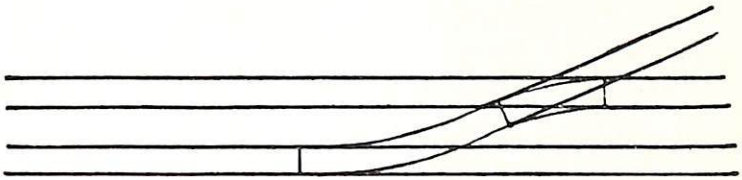
If the angle the branch line makes with the main line is a very flat one, a straight diamond will be used and reverse curves put at A. There should be a piece of straight between the reverse curves if possible.



Facing points can be avoided by the use of a crossover, or, if the angle of the main line with the

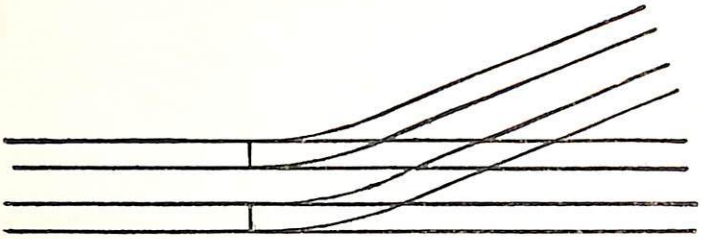


branch line is sufficiently flat (1 in 8 to 1 in 9), by the use of a diamond and slips.

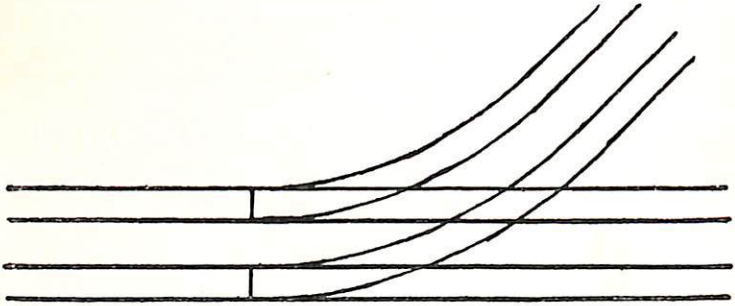


Both these arrangements, however, would entail additional shunting.

Junction of Double Branch Line.—If the angle the main line makes with the branch line is a flat one, a straight diamond will be used.

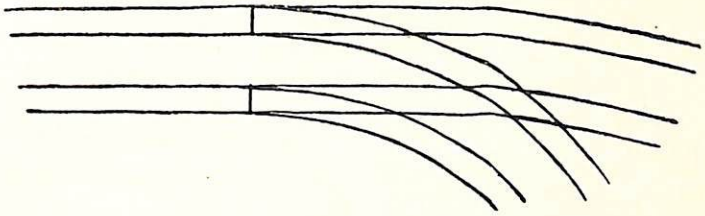


If the angle the main line makes with the branch line is a wide one, a curved diamond will have to be used. For method of working out the angles of the crossings, see Plate No 11

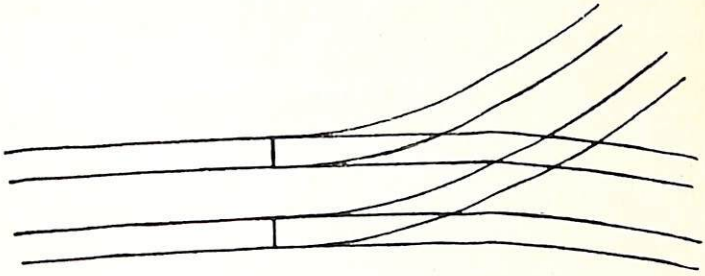


Junctions on Curved Double Main Lines.—These junctions will be either of similar or contrary flexure. Curved junctions of similar flexure are more satisfactory than curved junctions of contrary flexure, as superelevation of the curved rails in both roads cannot very well be obtained on the latter.

Similar flexure :—



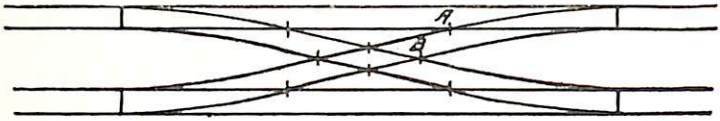
Contrary flexure :—



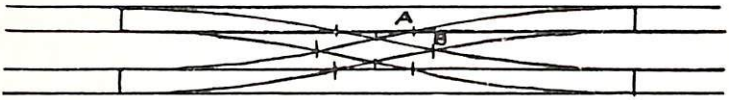
Care must be taken in either case that the radius of the curve in the branch line is not so great as to make the double crossings in the diamond flatter than 1 in $7\frac{1}{2}$ (see Curved Diamonds). For method of calculating the crossings, see Plates Nos. 12 and 14.

SCISSORS CROSSINGS

A scissors crossing may be described as a double crossover. It consists of four turnouts and a diamond.

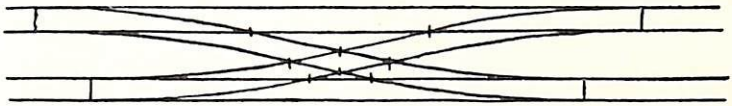


The crossing at B may fall in front of, behind, or opposite to the crossing at A, according to the distance between the tracks. If the tracks are at such a distance apart that the crossing at B falls behind, or opposite to the crossing at A, the angles of all the crossings in the diamond will be twice the angle of A. If the crossing at B falls in front of the crossing at A, then the crossing at B will be on the curve of the turnout, and theoretically will be of an angle less than twice A.



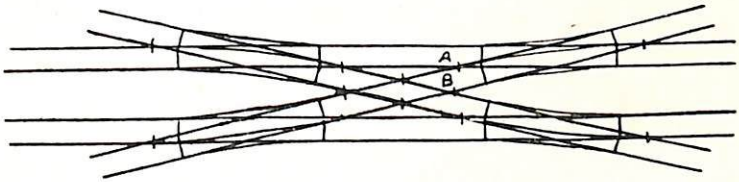
It is best, however, that the crossing at B should fall either well behind or well in front of the crossing at A, for if these crossings are directly opposite to one another the engine wheels will not be supported properly on either side when passing over the gaps, and a considerable jolt will occur. When it happens therefore that, owing to a fixed distance between the tracks, the crossings A and B face one another, the only remedy will be to decentralise the diamond, *i.e.*, place it nearer one track than the other, in which

case the distance between the turnouts will be greater on the farther side.



Some engineers prefer to put the diamond as close to one track as possible in order that the double crossing in the diamond and the two ordinary crossings in that track may be made to fit together and used as a standard irrespective of the distance between the tracks.

If it is desired to cross the main line at any or all of the four turnouts in the scissors crossing, diamonds and slips can be introduced.



In putting slips into a scissors crossing, however, it must be noted that in the case in which the crossing B falls in front of the crossing A, there is a possibility of the blades in the slips coming too close to the fastenings of the crossing B, in which case either the blades would have to be shortened, or the leg of the crossing would have to be shortened, or, if the slips

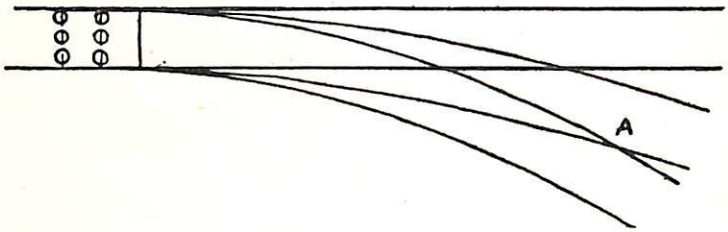
were required in one track only, the diamond could be moved slightly nearer the other side, as described above.

THREE-THROWS

A three-throw consists of two complete turnouts. The blades of both the turnouts lie side by side, the inside blade on either side being slightly shorter than the outside blade, so as to allow one set to close over the other. The heels of all the blades are in the same line.

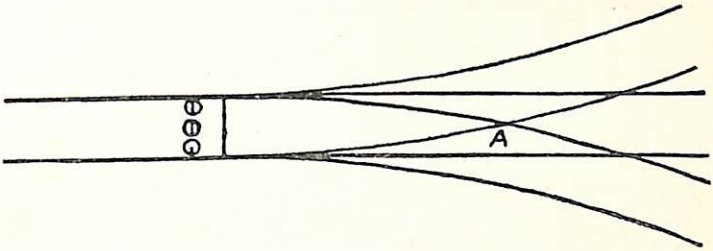
Three-throws may be of similar or contrary flexure.

Similar flexure :—



In this case the radii of the two turnouts will have to be different, and in order that the heels of both sets of points may fall in the same line, the curves will have to start at different tangents. For method of calculating the crossing A, see Plates Nos. 3 or 13.

Contrary flexure :—



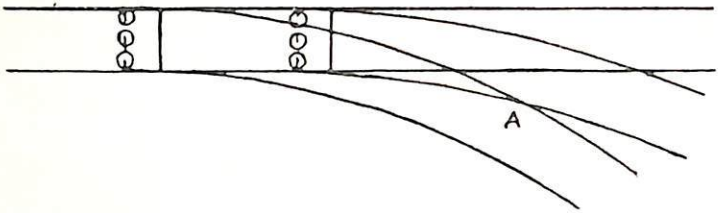
In this case the curves are usually of the same radius, and start at a common tangent. For method of calculating the crossing A, see Plate No. 14.

Three-throws are not recommended for main lines, or lines where there is fast traffic, as the double switches would be dangerous. They are only suitable for goods yards, or entrances to carriage and engine sheds, where saving of space is the chief consideration.

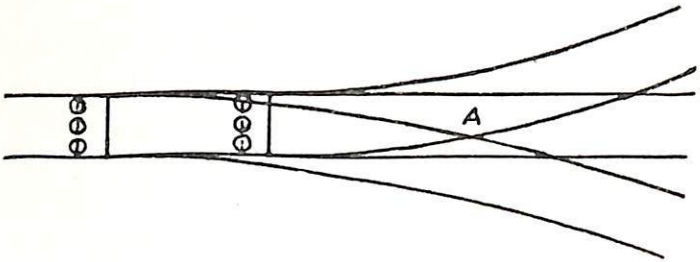
TANDEMS

This is a modification of the three-throw in which the switches are placed one set behind the other, the second set being placed as close to the first set as will allow room for the usual point-throw. Tandems may be of similar or contrary flexure.

Similar flexure :—



Contrary flexure :—



Tandems are suitable for main lines, or lines on which there is fast running. For methods of calculating the crossings at A, see Plates Nos. 3 and 4.

Although this text-book is primarily intended for the guidance of the permanent way engineer and draughtsman in the preparation of plans and designs, some consideration is necessary in the choice of the most suitable material to employ, especially for those places in the track subjected to heavy traffic. In this connection mention may be made of the fact that on account of its unique wear-resisting properties, Hadfield's patent "ERA" manganese steel has largely been adopted for switches, crossings, and curved rails at, for instance, busy junctions to important main line stations.

"ERA" manganese steel switches and crossings are built up from rolled rails, or, where preferred, the crossings can be produced as solid castings.

The reader is also referred to Messrs Summerson's advertisement, where the features of their patent adjustable connecting rod are set out.

APPENDIX

IT occasionally happens that a turnout has to be put at the tangent of a main line transition curve. The turnout may either be of similar or contrary flexure to the transition curve.

Approximate method of finding the lead and crossing angle of a turnout consisting of a circular arc from a transition curve of similar or contrary flexure, the circular arc and the transition curve starting at a common tangent. The transition curve is deemed to be a cubic parabola.

g = Gauge in feet.

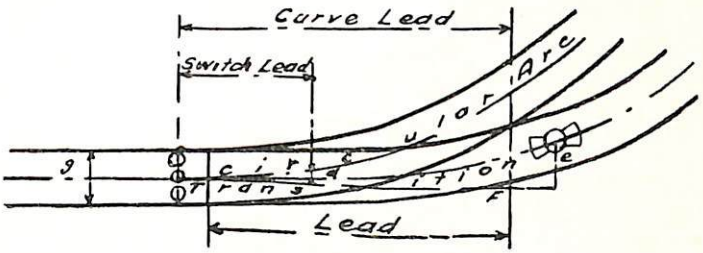
d = Clearance in feet.

$m = \frac{e}{f3}$.

θ = Angle of deflection of circular arc at crossing.

ϕ = Angle of deflection of transition curve at crossing.

Similar flexure :—



Required Lead.

Curve lead—

x_2 = Curve lead.

$x_1 = \sqrt{(2R - g)g}$.

R = Radius of outside rail of circular arc.

$$x_2 = x_1 - \left\{ \frac{x_1^3 - \frac{x_1^2}{2Rm} + \frac{g}{m}}{3x_1^2 - \frac{x_1}{Rm}} \right\}$$

Switch lead—

x_2 = Switch lead.

$x_1 = \sqrt{(2R - d)d}$.

R = Radius of centre line of circular arc.

Use equation as above, substituting d for g.

Lead = Curve lead − switch lead + length of blade.

Required Angle of Crossing.

x = Curve lead, as found above.

R = Radius of outside rail of circular arc.

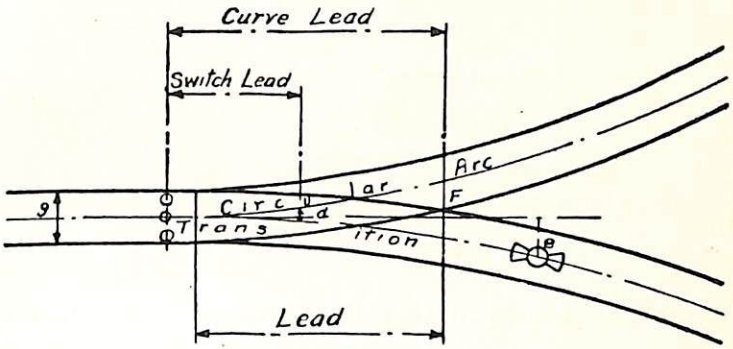
$\sin \theta = \frac{x}{R}$.

$\tan \phi = 3mx^2$.

Angle of crossing $= \theta - \phi$.

The radius of curvature of the transition at the crossing $= \frac{g}{2} + x \sec \phi \operatorname{cosec} 2\phi$.

Contrary flexure :—



Required Lead.

Curve lead—

x_2 = Curve lead.

$x_1 = \sqrt{(2R - g)g}$.

R = Radius of outside rail of circular arc.

$$x_2 = x_1 - \left\{ \frac{x_1^3 + \frac{x_1^2}{2Rm} - \frac{g}{m}}{3x_1^2 + \frac{x_1}{Rm}} \right\}$$

Switch lead—

x_2 = Switch lead.

$x_1 = \sqrt{(2R - d)d}$.

R = Radius of centre line of circular arc.

Use equation as above, substituting d for g.

Lead = Curve lead – switch lead + length of blade.

Required Angle of Crossing.

x = Curve lead, as found above.

R = Outside rail of circular arc.

$$\sin \theta = \frac{x}{R}.$$

$$\tan \phi = 3mx^2.$$

Angle of crossing $= \theta + \phi$.

The radius of curvature of the transition at the crossing $= \frac{g}{2} + x \sec \phi \operatorname{cosec} 2\phi$.

It might happen that the turnout should start a few feet behind the tangent of the transition, which distance is denoted by k.

The equation would then be, for similar flexure :—

$$x_2 = x_1 - \left\{ \frac{x_1^3 - \frac{(x_1 + k)^2}{2Rm} + \frac{g}{m}}{3x_1^2 - \frac{x_1 + k}{Rm}} \right\}$$

Curve lead $= x_2 + k$.

For contrary flexure :—

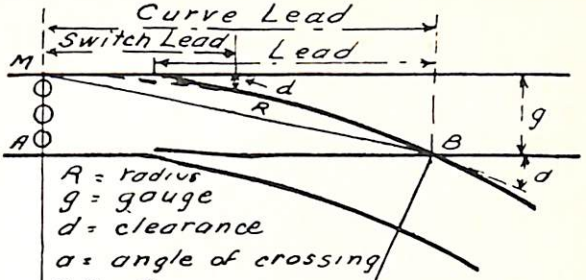
$$x_2 = x_1 - \left\{ \frac{x_1^3 + \frac{(x_1 + k)^2}{2Rm} - \frac{g}{m}}{3x_1^2 + \frac{x_1 + k}{Rm}} \right\}$$

Curve lead $= x_2 + k$.

The above method of solving the author's cubic equations is by Mr C. J. Merfield, Chief Assistant Astronomer of the Melbourne Observatory.

PLATES

Plate No 1



A = radius
g = gauge
d = clearance
a = angle of crossing
CB = R
AB = Curve Lead
MBA = $\frac{a}{2}$
MA = $\frac{g}{2}$

Req^d Lead – Given a. g.

AB = MA cot MBA
R = AB cosec a
Switch Lead = $\sqrt{2Rd}$
Lead = AB = switch lead + length of blade

Req^d ∠ a – Given R. g.

cos a = $\frac{CB - MA}{CB}$
or Vers a = $\frac{MA}{CB}$

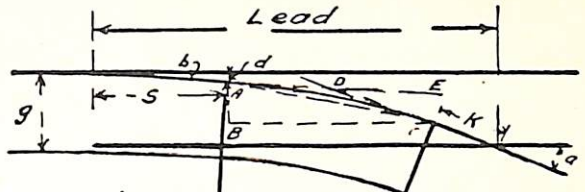
Req^d Rad.– Given ∠ a g

$R = \frac{MA}{\text{Vers } a}$

Req^d Lead – Given R g

Cos a = $\frac{CB - MA}{CB}$
AB = MA cot MBA
Switch Lead = $\sqrt{2Rd}$
Lead = AB – Switch Lead + length of blade

Plate No. 2



R = radius
g = gauge
d = clearance
a = angle of crossing
s = length of blade
K = " of leg of crossing
b = angle of blade with stock rail

$ACB = \frac{a+b}{2}$

$EDC = a - b$

R

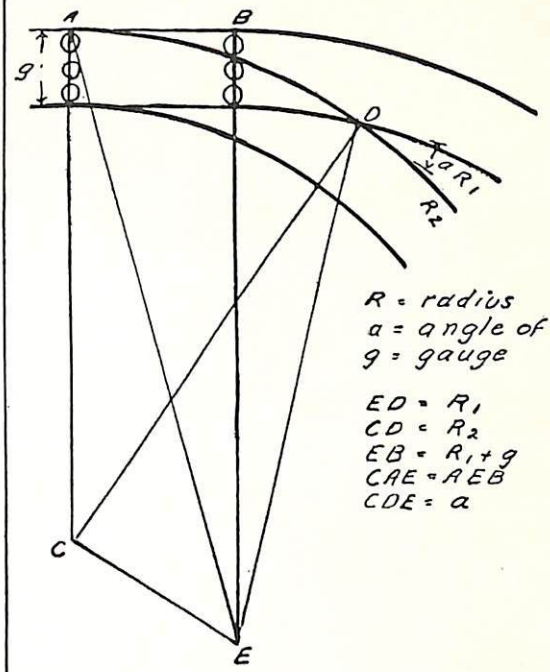
Req^d Radius

$$R = \frac{(g - d - k\sin a)\ \mathrm{cosec}\ ACB}{2} \times \mathrm{cosec}\ \frac{EDC}{2}$$

Req^d Lead

$$\text{Lead} = (g - d - k\sin a)\cot ACB + k\cos a + S$$

Plate № 3



R = radius
a = angle of crossing
g = gauge

ED = R_1
CD = R_2
EB = $R_1 + g$
CAE = AEB
CDE = a

Req^d R_2 – Given ∠ a, AB, R_1, g

$$\tan AEB = \frac{AB}{BE}$$

$$AE = BE \sec AEB$$

$$R_2 = \frac{AE^2 - DE^2}{2(AE \cos CAE - DE \cos CDE)}$$

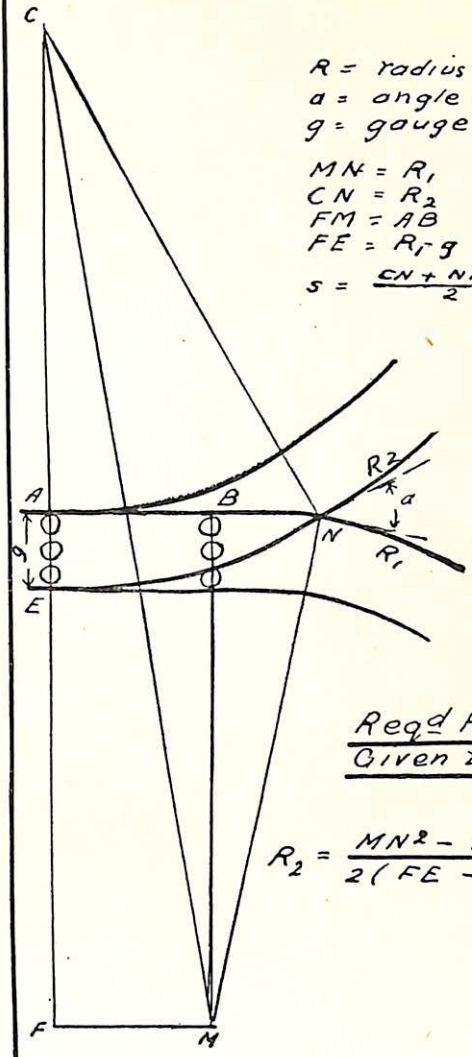
Req^d ∠ a – Given R_1. R_2. AB. g.

$$CE = \sqrt{AB^2 + (R_1 + g - R_2)^2}$$

$$s = \frac{CD + DE + CE}{2}$$

$$\sin \frac{CDE}{2} = \sqrt{\frac{(S - DC)(S - DE)}{DC \times DE}}$$

Plate No 4



R = radius
a = angle of crossing
g = gauge

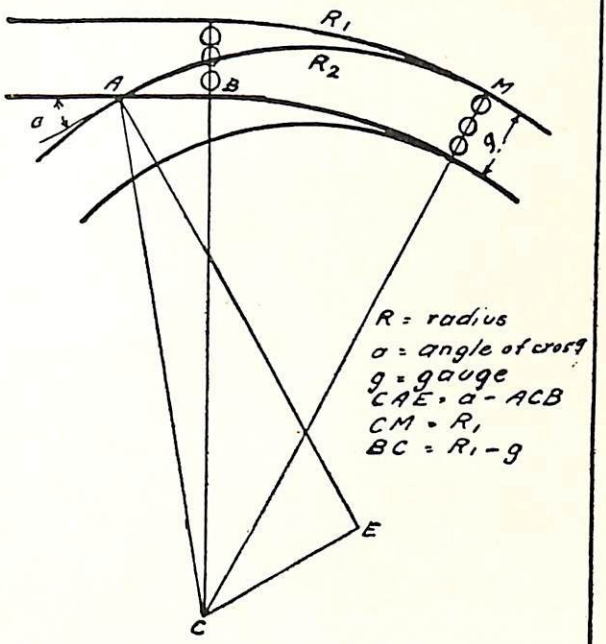
$MN = R_1$
$CN = R_2$
$FM = AB$
$FE = R_1 - g$

$$s = \frac{CN + NM + CM}{2}$$

Req^d R_2
Given $\angle a$ g. R_1 AB.

$$R_2 = \frac{MN^2 - FM^2 - FE^2}{2(FE - MN \cos a)}$$

Plate No 5



R = radius
α = angle of crossg
g = gauge
CAE = α - ACB
CM = R1
BC = R1 - g

Reqd R_2 - Given R_1, AB, α, g.

$\tan ACB = \frac{AB}{BC}$

$AC = AB \operatorname{cosec} ACB$

$AE = AC \cos CAE$

$CE = AC \sin CAE$

$$R_2 = \frac{CM^2 - AE^2 - CE^2}{2(CM - AE)}$$

Plate No 6

R = Radius
g = gauge
a = angle of crossing

EAD = a + ADB
DB = R_1
DM = $R_1 - g$

Req^d R_2 – Given AB, R_1, a, g

$$\tan ADB = \frac{AB}{BD}$$

AD = AB cosec ADB
ED = AD sin EAD
AE = AD cos EAD

$$R_2 = \frac{AE^2 + ED^2 - DM^2}{2(DM - AE)}$$

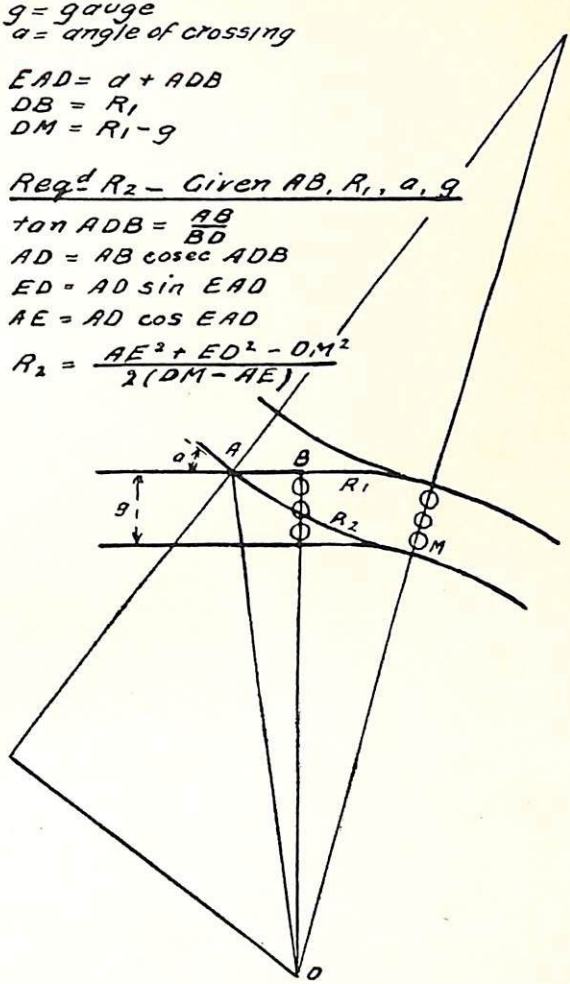
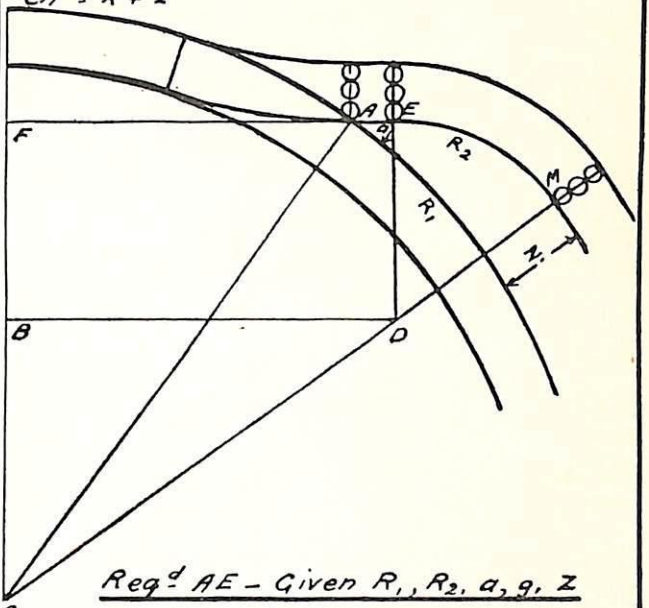


Plate No 7

R = Radius
z = distance between rails
a = angle of crossing

FCA = a
CA = R_1
CD = $R_1 - R_2 + z$
CB = FC − R_2
FE = BD
CM = R + z



Req^d AE – Given R_1, R_2, a, g, z

FA = CA sin FCA

FC = CA cos FCA

BD = $\sqrt{CO^2 - CB^2}$

AE = BD − FA

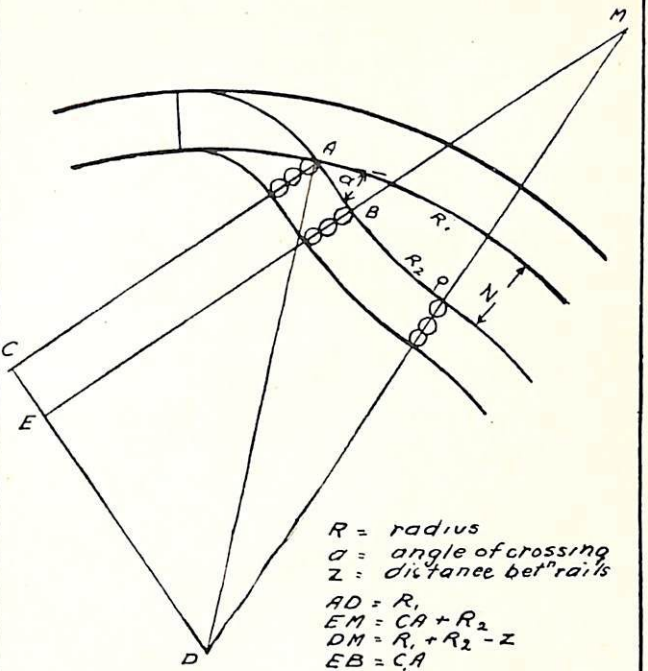
Req^d R_2 – Given AE. R_1. a. z

find FA. FC. as above

BD = FA + AE

$$R_2 = \frac{CM^2 - BD^2 - FC^2}{2(CM - FC)}$$

Plate N°8



R = radius
a = angle of crossing
z = distance bet" rails

AD = R_1
EM = CA + R_2
DM = R_1 + R_2 - z
EB = CA
CAD = a
DP = R_1 - z

Req^d AB - Given R_1, R_2, a, z

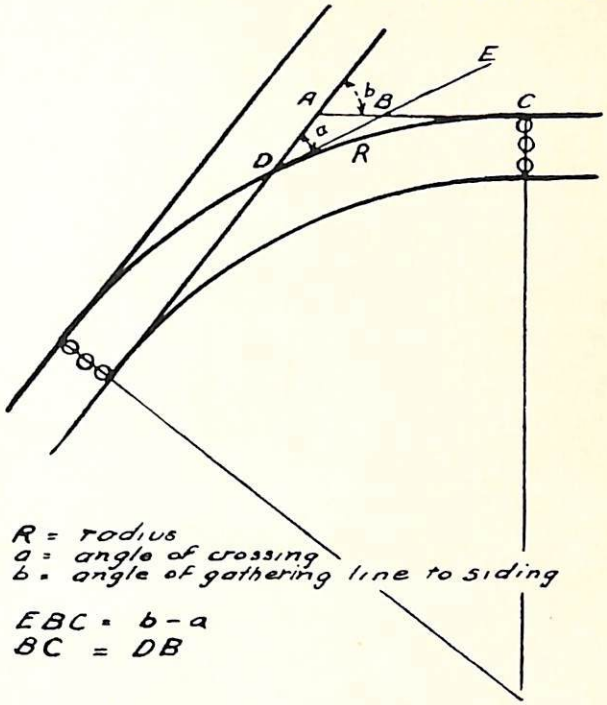
CA = AD cos CAD
CD = AD sin CAD
ED = $\sqrt{DM^2 - EM^2}$
AB = CD - ED

Req^d R_2 - Given AB, R_1, a, z.

find CA, CD as above
ED = CD - AB

$$R_2 = \frac{EB^2 + ED^2 - DP^2}{2(DP - EB)}$$

Plate No 9



R = radius
a = angle of crossing
b = angle of gathering line to siding

$EBC = b - a$

$BC = DB$

Req'd DA - Given R, a, b.

$DB = R \tan \frac{EBC}{2}$

$DA = \frac{DB \sin EBC}{\sin b}$

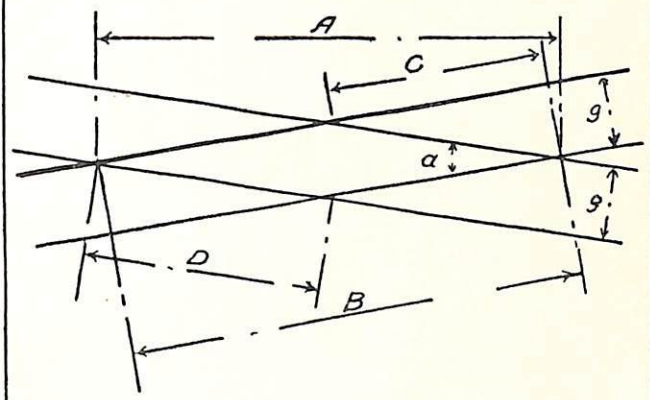
Req'd AC - Given R, a, b.

$DB = R \tan \frac{EBC}{2}$

$AB = \frac{DB \sin a}{\sin b}$

$AC = AB + BC$

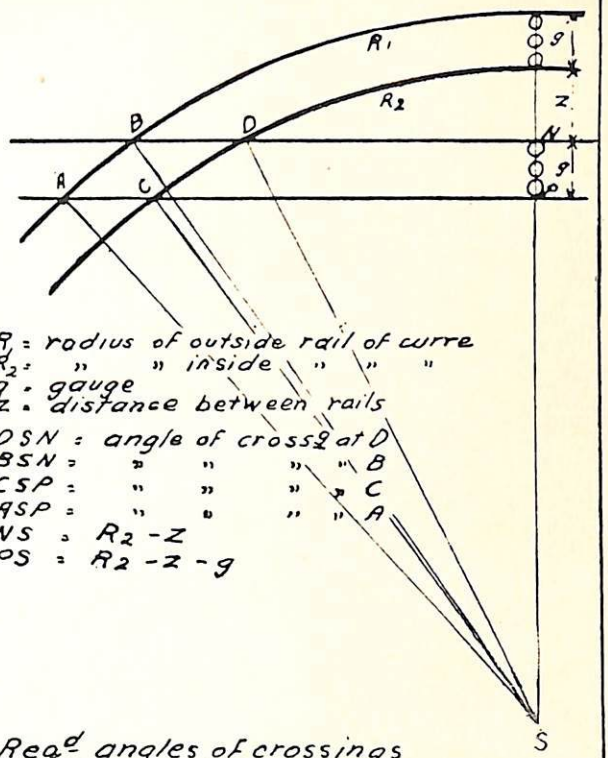
Plate No. 10



g = gauge
a = angle of crossings

$A = g \operatorname{cosec} \frac{a}{2}$
$B = g \cot \frac{a}{2}$
$C = g \cot a$
$D = g \operatorname{cosec} a$

Plate No. 11



R_1 = radius of outside rail of curve
R_2 = " " inside " " "
g = gauge
z = distance between rails

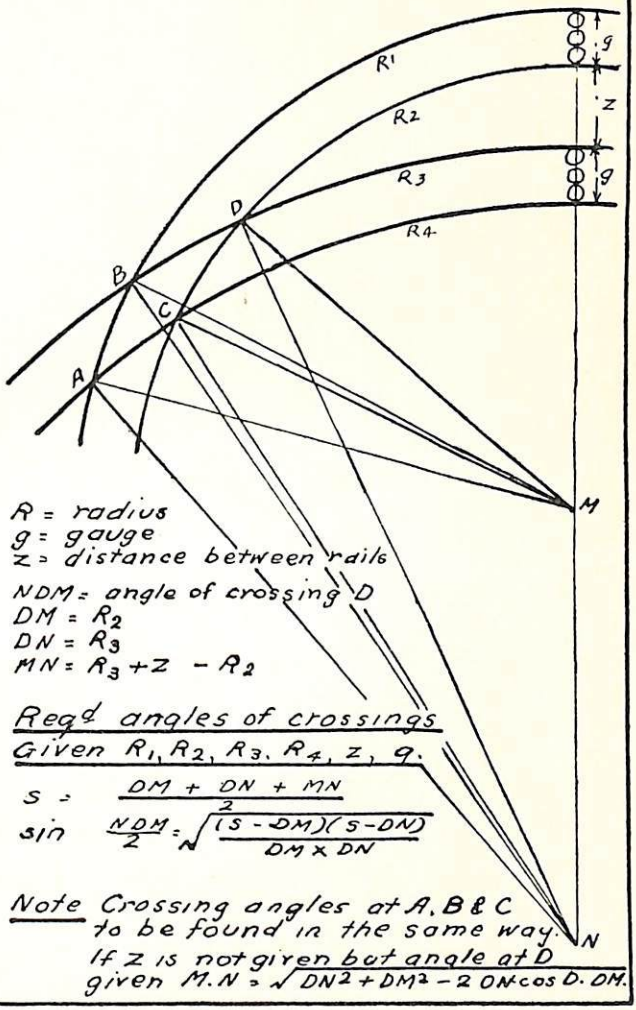
DSN = angle of crossing at D
BSN = " " " B
CSP = " " " C
ASP = " " " A
$NS = R_2 - z$
$PS = R_2 - z - g$

Reqd angles of crossings
Given z, R, R_2, g.

$\cos DSN = \frac{NS}{DS}$
" $BSN = \frac{NS}{BS}$
" $CSP = \frac{PS}{CS}$
" $ASP = \frac{PS}{AS}$

Note If z is not given but the angle at D is given $z = R_2$ vers DSN.

Plate No 12



R = radius
g = gauge
z = distance between rails
NDM = angle of crossing D
DM = R_2
DN = R_3
MN = $R_3 + z - R_2$

Reqd angles of crossings

Given R_1, R_2, R_3, R_4, z, g.

$$S = \frac{DM + DN + MN}{2}$$

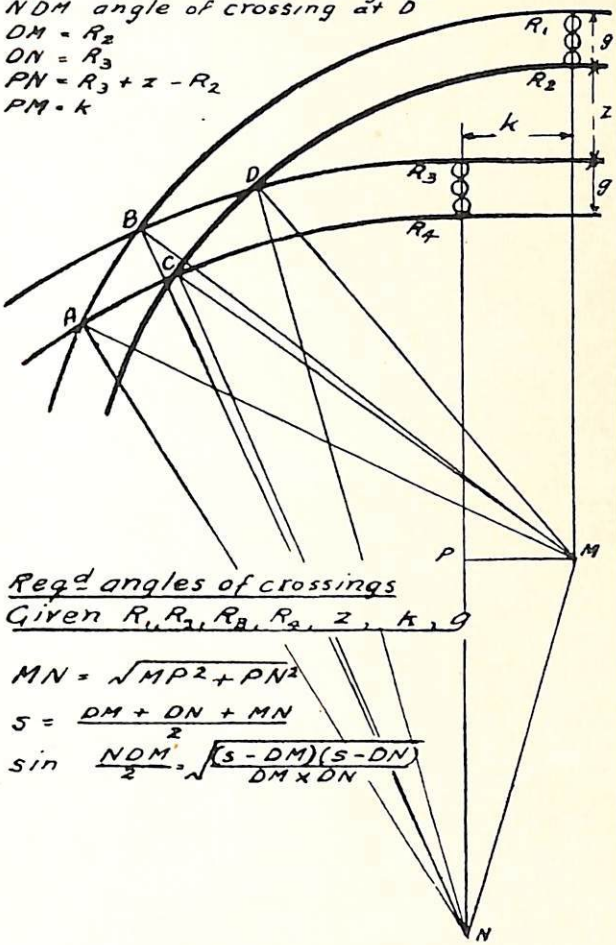
$$\sin \frac{NDM}{2} = \sqrt{\frac{(S - DM)(S - DN)}{DM \times DN}}$$

Note Crossing angles at A, B & C to be found in the same way.

If z is not given but angle at D given $MN = \sqrt{DN^2 + DM^2 - 2\,DN \cdot \cos D \cdot DM}$.

Plate Nº 13

R = radius
g = gauge
z = distance between rails
k = " " tangents
NDM angle of crossing at D
$OM = R_2$
$ON = R_3$
$PN = R_3 + z - R_2$
$PM = k$



Reqd angles of crossings
Given $R_1, R_2, R_3, R_4, z, k, g$

$$MN = \sqrt{MP^2 + PN^2}$$

$$s = \frac{DM + ON + MN}{2}$$

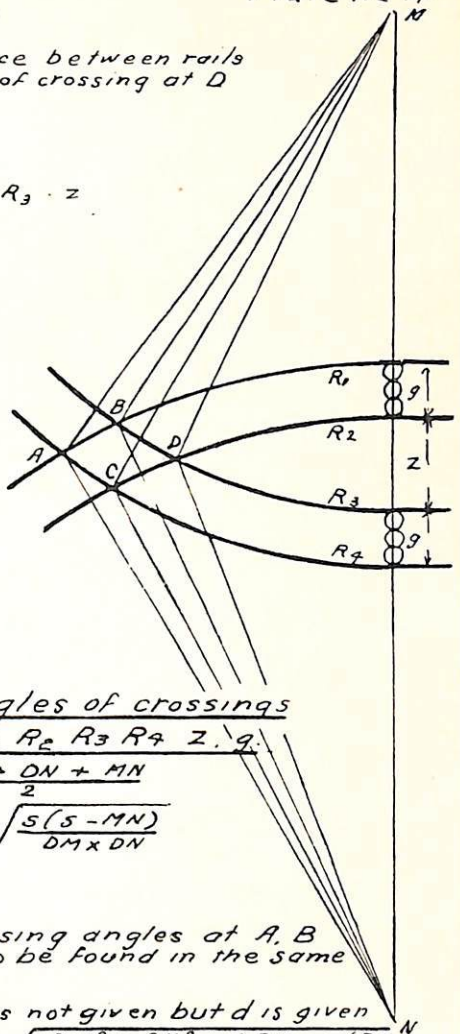
$$\sin \frac{NDM}{2} = \sqrt{\frac{(s - DM)(s - DN)}{DM \times DN}}$$

Note Angles of A B & C to be found in the same way.

Plate Nº 14

R = radius
g = gauge
z = distance between rails
d = angle of crossing at D

$DN = R_2$
$DM = R_3$
$MN = R_2 + R_3 \cdot z$



Req^d angles of crossings
Given R_1 R_2 R_3 R_4 z. g.

$$s = \frac{DM + DN + MN}{2}$$

$$\sin \frac{d}{2} = \sqrt{\frac{s(s - MN)}{DM \times DN}}$$

Note Crossing angles at A, B & C to be found in the same way

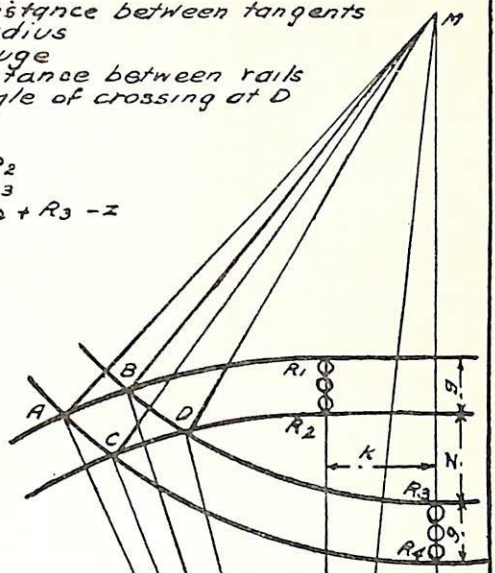
If z is not given but d is given

$$MN = \sqrt{DM^2 + DN^2 + 2\,DM \cos d\, DN}$$

Plate Nº 15

k = distance between tangents
R = radius
g = gauge
z = distance between rails
d = angle of crossing at D

$DN = R_2$
$DM = R_3$
$MP = R_2 + R_3 - z$
$PN = k$



Reqd angles of crossings
Given R_1 R_2 R_3 R_4, z, k, g

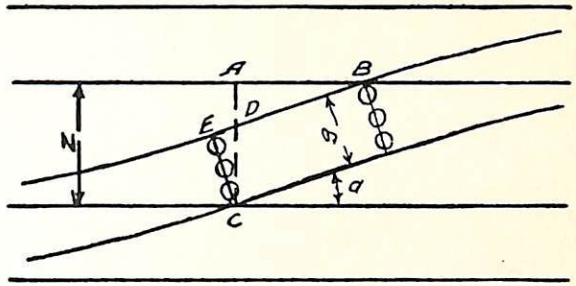
$$MN = \sqrt{MP^2 + PN^2}$$

$$s = \frac{DM + ON + MN}{2}$$

$$\sin \frac{d}{2} = \sqrt{\frac{s(s - MN)}{DM \times DN}}$$

Note Crossing angles at A, B & C to be found in the same way

Plate Nº 16

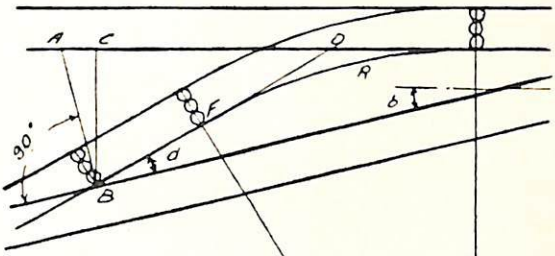


z - distance between rails
g = gauge
a = angle of crossing
AC = z
CE = g
DCE = a
ABD = a

Reqd distance AB.
Given z, g, & a.

CD = CE sec DCE
AD = AC - CD
AB = AD cot ABD

Plate Nº 17



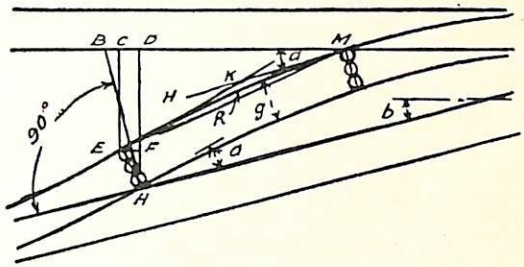
R : radius
a . angle of crossing
b . angle of tracks to one another

ABC = b
CDB = a + b

Reqd BF - Given AB. a. b. R.

BC = AB cos ABC
BD = BC cosec CDB
FD = R tan $\frac{CDB}{2}$
BF = BD - FD

Plate No. 18



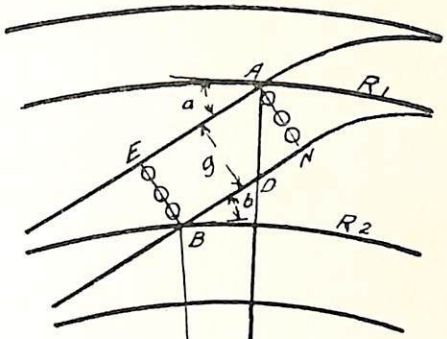
R = radius
a = angle of crossings
b = angle of tracks to one another
g = gauge

$EA = g$
$BAD = b$
$HKE = b$
$EAF = a + b$
$CME = a + \frac{b}{2}$
$CE = DF$

Req^{d} R Given a b g & AB

$AD = AB \cos BAD$
$AF = EA \cos EAF$
$DF = AD - AF$
$EM = CE \operatorname{cosec} CME$
$R = \frac{EM}{2} \operatorname{cosec} \frac{HKE}{2}$

Plate No 19



g = gauge
a = angle of crossing at A
R = radius
b = angle of crossing at B

AN = g
DC = $R_1 - AD$
BC = R_2
NAD = a
BDC = 90° − a
EA = NB

Req^d EA & b

Given a. R_1. R_2. g.

$DA = AN \sec NAD$

$ND = AN \tan NAD$

$DBC = \frac{DC \sin BDC}{BC}$

$DCB = 180 - (BDC + DBC)$

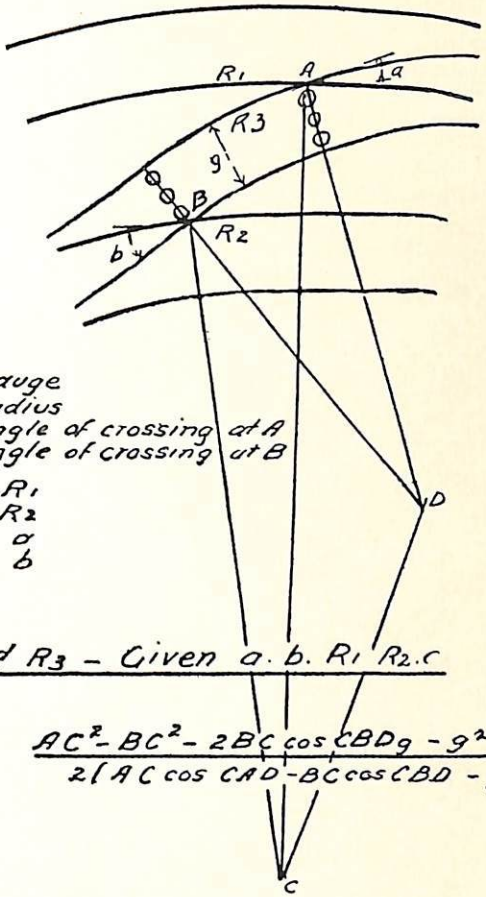
$DB = \frac{BC \sin DCB}{\sin BDC}$

$NB = ND + DB$

$b = DBC - 90°$

C

Plate Nº 20



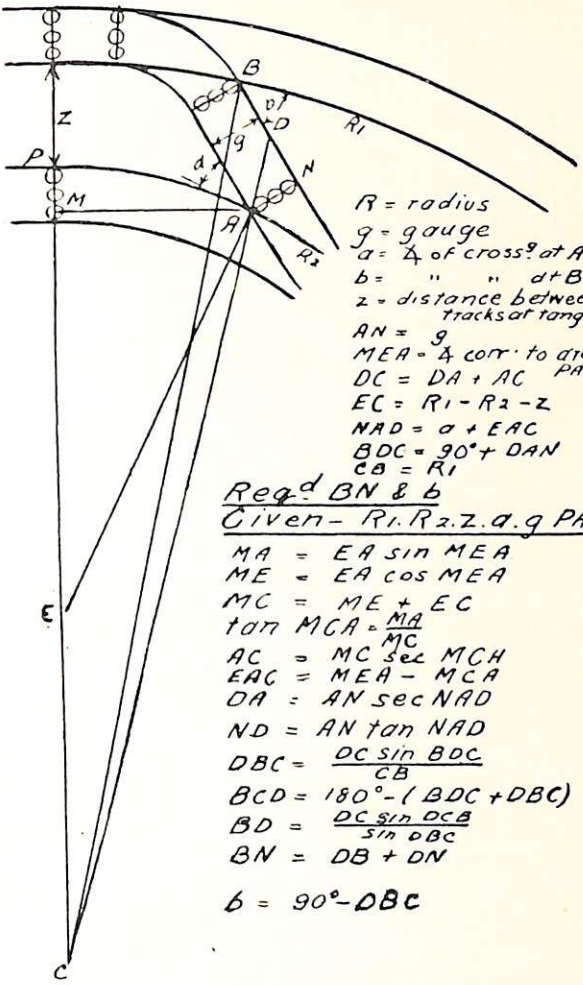
g = gauge
R = radius
a = angle of crossing at A
b = angle of crossing at B

AC = R1
BC = R2
CAD = a
CBD = b

Reqd R_3 – Given a. b. R_1 R_2. c

$$R_3 = \frac{AC^2 - BC^2 - 2BC\cos CBD\,g - g^2}{2(AC\cos CAD - BC\cos CBD - g)}$$

Plate No 21



R = radius
g = gauge
a = ∠ of cross^{g} at A
b = " " a+B
z = distance between tracks at tang
AN = g
MEA = ∠ corr. to a/c PA
DC = DA + AC
EC = R1 - R2 - z
NAD = a + EAC
BDC = 90° + DAN
CB = R1

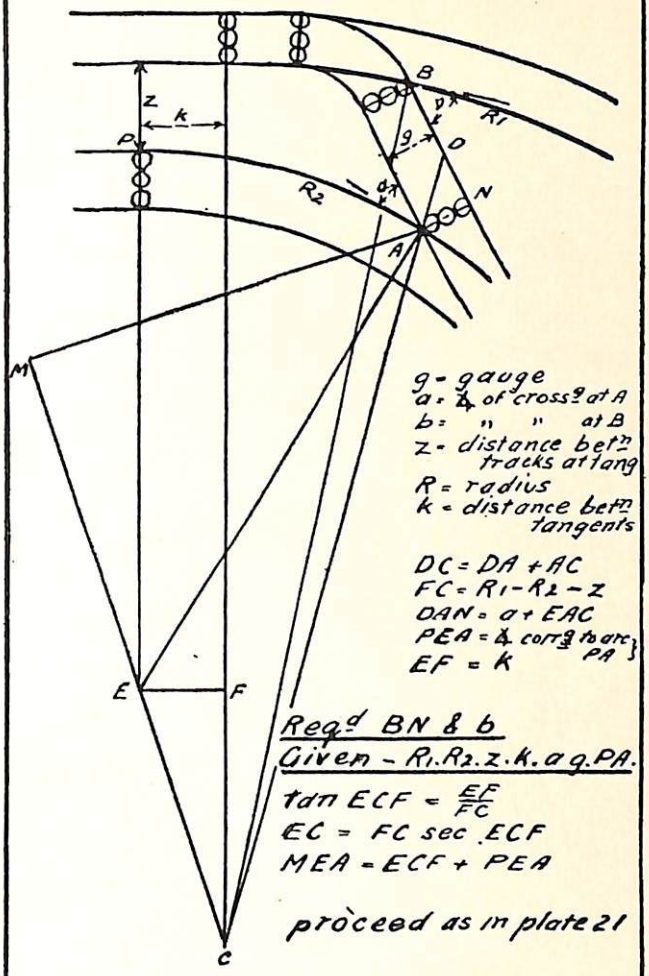
Req^{d} BN & b

Given - R1. R2. z. a. g PA.

MA = EA sin MEA
ME = EA cos MEA
MC = ME + EC
tan MCA = $\frac{MA}{MC}$
AC = MC sec MCH
EAC = MEA - MCA
DA = AN sec NAD
ND = AN tan NAD
DBC = $\frac{DC \sin BDC}{CB}$
BCD = 180° - (BDC + DBC)
BD = $\frac{DC \sin DCB}{\sin DBC}$
BN = DB + DN

b = 90° - DBC

Plate No. 22



g - gauge
a = ∠ of cross^{g} at A
b = " " at B
Z - distance bet^{n} tracks at tang
R = radius
k = distance bet^{n} tangents

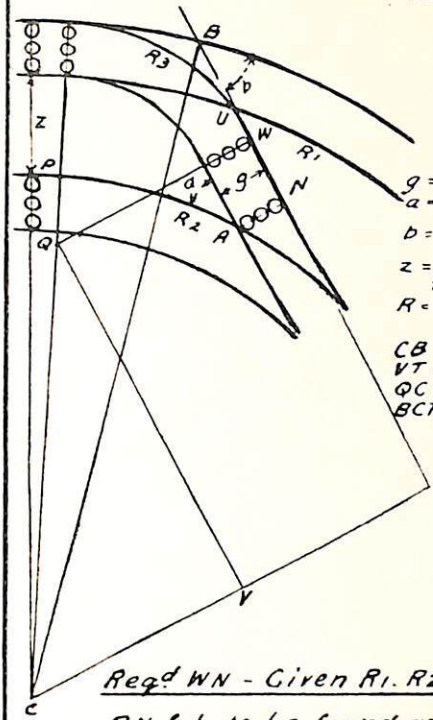
DC = DA + AC
FC = R1 − R2 − Z
DAN = a + EAC
PEA = ∠ corr^{g} to arc PA
EF = K

Req^{d} BN & b
Given - R1.R2.Z.K.a.g.PA.

tan ECF = $\frac{EF}{FC}$
EC = FC sec ECF
MEA = ECF + PEA

proceed as in plate 21

Plate No 23



g = gauge
a = angle of crossing $\frac{g}{A'A}$
b = angle at B
z = distance between tracks at tangents
R = radius

CB = R1 + g
VT = R3
QC = R1 − R3 + g
BCT = b

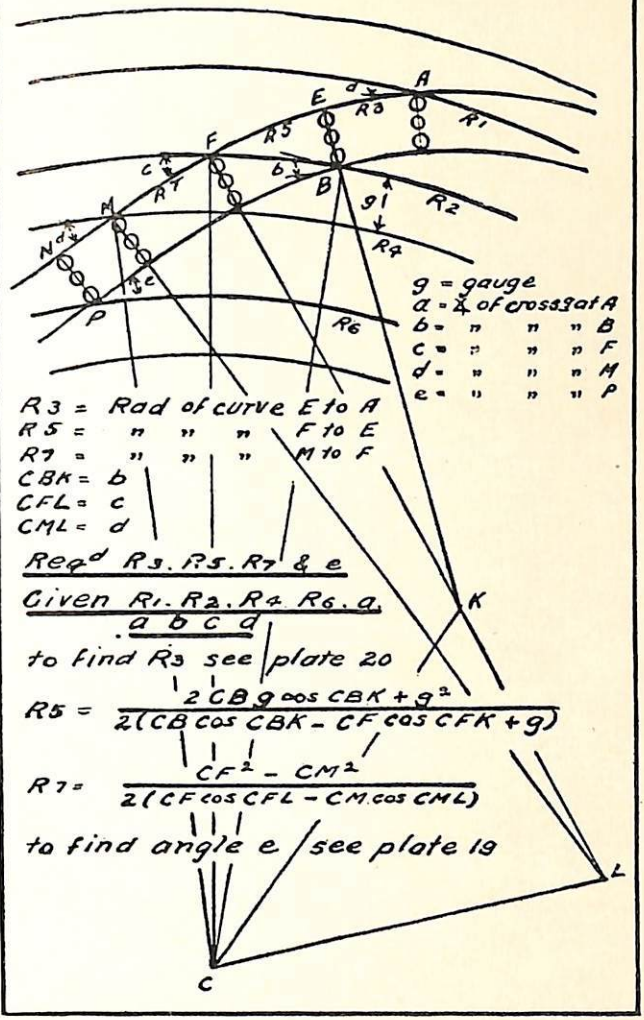
Reqd WN - Given R1. R2. R3. PA. z. g. a.

BN & b to be found as in plate 21
(Note CB = R1 + g)

$BT = CB \sin BCT$
$CT = CB \cos BCT$
$CV = CT - VT$
$QV = \sqrt{QC^2 - CV^2}$
$BW = BT - QV$
$WN = BN - BW$

Note. The angle of crossing U may be found as in turnouts of similar flexure having given R1. R3. g.

Plate N° 24


A
E
F
B
M
N
P
K
L
C
R1
R2
R3
R4
R5
R6
R7
g
g = gauge
a = ∠ of cross at A
b = " " " B
c = " " " F
d = " " " M
e = " " " P
R3 = Rad of curve E to A
R5 = " " " F to E
R7 = " " " M to F
CBK = b
CFL = c
CML = d
Req^d R3. R5. R7 & e
Given R1. R2. R4. R6. a. b c d
to find R3 see plate 20
R5 = (2 CB g cos CBK + g²) / 2(CB cos CBK − CF cos CFK + g)
R7 = (CF² − CM²) / 2(CF cos CFL − CM cos CML)
to find angle e see plate 19

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Buildings 61 acres

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STEEL CASTINGS

RAILWAY WHEELS, AXLES AND TYRES, CAST STEEL WHEEL CENTRES, RAILWAY RAMPS, TOOL STEELS, Etc.

ERA
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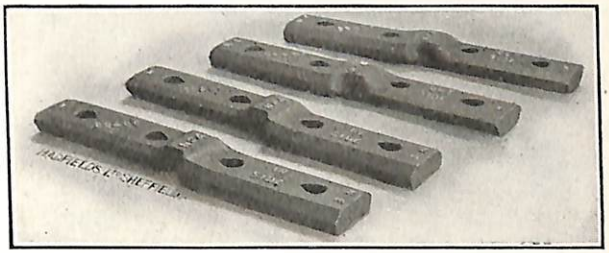
MANGANESE STEEL
SPECIAL
LIFT or JUNCTION FISH PLATES
are absolutely reliable under the severest working conditions



When connecting Rails of different section they ensure
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A MINIMUM OF LABOUR WHEN JOINING RAILS OF DIFFERING SECTIONS OR PARTLY WORN AND NEW RAILS
PERFECT RUNNING ALIGNMENT OF THE RAILS

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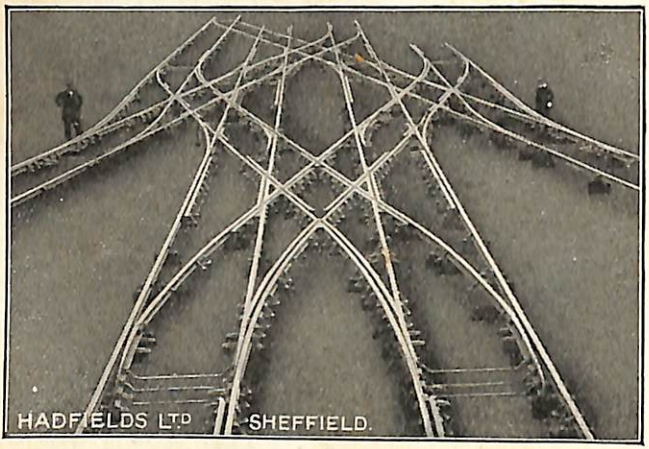

The above is reproduced from a photograph showing the application of Hadfield's Patent "ERA" Manganese Steel Rolled Rails on the Buenos Ayres Electric Subway

The total weight supplied for this and other stations on the same Railway was over 630 tons

Sole Makers of Hadfield's Patent

MANGANESE STEEL

THE SUPREME MATERIAL

FOR

RAILWAY AND TRAMWAY TRACK-WORK, Etc.

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AND

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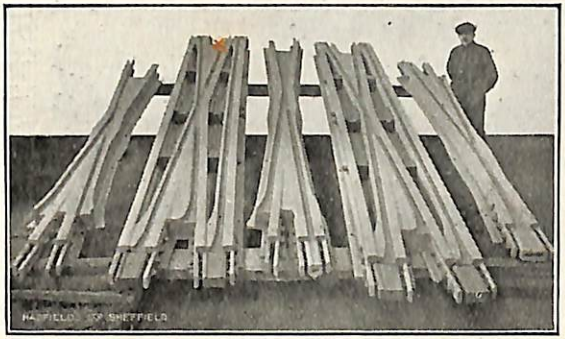

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Hadfield's have a new and up-to-date Rolling Mill Plant electrically driven, including a 28-inch Reversing Mill, which, amongst other products, will produce rails in Hadfield's Patent "ERA" Manganese Steel of any standard section.

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